EFFECTS OF DIFFERENT DIETS ON WEIGHT GAIN, CARCASS AND MEAT QUALITY CHARACTERISTICS OF TWO INDIGENOUS CATTLE BREEDS OF TANZANIA

BY

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ABSTRACT

Two experiments were conducted to study the effects of different diets on weight gain, carcass and meat quality characteristics of two indigenous cattle in Tanzania. In Experiment (Expt.) 1, 60 Tanzania Shorthorn Zebu (TSHZ) (1.5 to 2.5 years old and 99 ±11 kg LWT) and 60 Boran (1 to 2 years old and 167 ± 8 kg LWT) steers were randomly allocated to five dietary treatments in a 2 x 5 factorial arrangement during the wet season. While in Expt. 2, 36 TSHZ (3 to 4 years old and 177 ± 9 kg LWT) and 36 Boran (2 to 3 years old and 225 ± 12 kg LWT) steers were randomly allocated to three dietary treatments in a 2 x 3 factorial arrangements during the dry season. Diets in Expt. 1 were GrazC00 where animals were purely grazing as control, GrazC50 (grazing animals offered 50 % *ad libitum* concentrate intake) while diets HayC60, HayC80 and HayC100 comprised animals given *ad libitum* hay plus 60, 80 and 100 % of *ad libitum* concentrate intake, respectively. Similar diets were used in Expt. 2 except HayC60 and HayC80 were excluded. The concentrate contained maize meal (380), cotton seed cake (130), molasses (470), mineral mix (10), salt (5) and urea (5) g/kg feed to give 125 g CP and 12 MJ ME per kg DM. The two experiments lasted 100 and 90 days, respectively, for Expt. 1 and Expt. 2 after which all animals were slaughtered. Data on performance, carcass and meat characteristics were recorded and analysed. Net returns were calculated for each treatment. ADG and DP increased with concentrate offered in both Expt. 1 and 2. Shear force were lower ($P<0.05$) in Boran than TSHZ. Shear force values decreased ($P<0.05$) with increasing level of concentrate offered. Shear force decreased ($P<0.05$) with increase in ageing time. Positive net returns were only obtained when carcasses were sold at prices higher than the actual market prices for meat at the time of the two experiments. In conclusion, the quantity and quality of meat produced from indigenous

cattle breeds in Tanzania can be improved through feeding fattening diets but this can only be profitable when meat is sold at higher prices than the current conventional prices of meat.

DECLARATION

I, *ANGELLO JOSEPH TIGANNA MWILAWA*, do declare to the Senate of Sokoine University of Agriculture that this thesis is my own original work and has never been submitted, nor concurrently being submitted in any other University.

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This thesis is dedicated to my beloved wife; Fanikio/Bella, children Andrew and Amos; and to my late parents Mr Joseph Tiganna Mwilawa and Mrs Lucia Joseph Mwilawa.

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LIST OF ABBREVIATIONS AND SYMBOLS

ADF	Acid detergent fiber
ADG	Average daily gain
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
BWT	Body Weight
Cm	Centimetre
CP	Crude Protein
CRD	Completely Randomized Design
CSC	Cotton seed cake
D	Day
DASP	Department of Animal Science and Production
DFD	Dry, firm and dark
DM	Dry matter
DANIDA	Danish International Development Agency
DOMD	Digestible organic matter in the dry matter
DP	Dressing Percentage
EBW	Empty body weight
EE	Ether Extract
ENRECA	Enhancement of Research Capacity
FAO	Food and Agriculture Organization of the United Nations
FCR	Feed Conversion Ratio
FLW	Final liveweight
G	Gram

GDP	Gross domestic Product
GIT	Gastrointestinal tract
GLM	General Linear Model
GM	Gross margin
GPS	Global Position System
Graz+C00	Grazing alone –common practice -control
Graz+C50	Grazing + 50% *ad libitum* concentrates
H	Hour
Ha	Hectare
Ha	Hectare
Hay+C100	*ad libitum* hay intake + *ad libitum* concentrates intake
Hay+C60	*ad libitum* hay intake + 60% *ad libitum* concentrates intake
Hay+C80	*ad libitum* hay intake + 80% *ad libitum* concentrates intake
HCW	Hot carcass weight
IGMAFU	Income Generation through Market Access and Improved Feed Utilization
ILRI	International Livestock Research Institute
IVOMD	*In vitro* organic matter digestibility
Kg	Kilogram
LD	*Longissimus dorsi*
LSMeans	Least Square Means
LW	Live weight
MAFS	Ministry of Agriculture and Food Security
ME	Metabolizable energy
MJ	Megajoule

MLDF	Ministry of Livestock Development and Fisheries
MLFD	Ministry of Livestock Fisheries and Development
N	Nitrogen
NARCO	National Ranching Company
NDC	National Development Cooperation
NDF	Neutral detergent fiber
NLRI	National Livestock Research Institute
NRs	Net returns
pHu	Ultimate pH
PM	Post-mortem
PSE	Pale, soft and exudates
SAAFI	Sumbawanga Agricultural and Animal Feeds Industries
SAS	Statistical Analysis System
SUA	Sokoine University of Agriculture
TDMI	Total dry matter intakes
TLU	Tropical Livestock Unit
TSAP	Tanzania Society of Animal Production
Tshs	Tanzania Shillings
TSHZ	Tanzania Shorthorn Zebu
URT	United Republic of Tanzania
US $	United States Dollar
WBSF	Warner-Bratzler shear force
WHC	Water holding capacity

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Indigenous cattle in Tanzania comprise of Tanzania Shorthorn Zebu (TSHZ), Boran and Ankole (Msanga *et al.*, 2001) and they play a significant role to the income and livelihoods of livestock keepers. The Ministry of Livestock and Fisheries Development (MLDF) (2009) estimated that of the 19.1 million cattle population in Tanzania, beef is produced from agro-pastoral (80 %) and pastoral (14%) systems and the remaining 6% come from the commercial ranches. Despite this large cattle population, the livestock sector has not performed to the expected potential resulting to low productivity leading to low income by the livestock keepers. The reasons for the low performance of the beef industry have been studied by several workers. Reviews by Mpiri (1991; 1994) and URT (2005) reported low productivity coefficients of the Tanzania indigenous cattle under traditional sector as characterized by low herd growth rate (0.54 %) and low calving rate (40-50 %). Other traits of economic importance that are characterized by low coefficients included old age at weaning (180-210 days), high calf mortality (> 25 %) and adult mortality (8-10 %), low mature weight (200-300 kg) and off take rate (8-10 %) and low carcass weight (100-175 kg). Animals are slaughtered at old age (6-7 years) resulting into tough meat (Mpiri, 1994). Despite the poor performance of the indigenous cattle, it is the most available animal resource for beef production in Tanzania (94 % of the total cattle population) and the animals are hardy and highly adaptable to the local environment.

According to a review by Msanga *et al.* (2001) indigenous cattle of Tanzania (TSHZ, Ankole and Boran) belong to *Bos indicus* species and have some beef characteristics with good fertility (calving interval of 18-24 months). However, it is likely that without addressing the current poor productivity of the indigenous cattle and by developing serious interventions in the whole meat value chain in Tanzania, it will not be possible to have a commercial, vibrant and competitive beef industry. Livestock stakeholders are challenged to come up with breeds that can perform better under Tanzanian condition using locally available resources such as feedstuffs. The Government of Tanzania has attempted to meet these challenges by contracting several experts to explore possible interventions including that of the construction of modern abattoirs (Ashimogo and Greenhalgh, 2007) and improving the market outlets of animals from livestock keepers to abattoirs (Kinunda-Rutashobya, 2003). In addition, various studies have been conducted to look into the resources for production of quality beef (Nandonde, 2008), and market availability and accessibility of quality meat (Mapunda, 2007). The attitude of pastoralists and agro-pastoralists in selling cattle (Haule *et al.*, 2010 and Sambali, 2010) have also been assessed and documented. In several occasions, The President of the United Republic of Tanzania, Hon. Jakaya Mrisho Kikwete has emphasized on the need to improve the beef industry through finishing beef under feedlot conditions (TSAP opening speech, 2007). Such challenges that call for improved productivity of livestock should be met by making informed decisions and these calls for research on factors that affect beef cattle productivity. It is therefore important to understand the factors that affect production of quality beef.

Several factors have been reported to influence production of quality beef including breed, nutrition (feed combinations, energy level, protein and mineral contents), sex and the age of the animals (Purslow, 2002; Warriss, 2004). Several studies have demonstrated that there are differences among breed on the onset and rate of fattening (Strydom *et al.*, 2000) and there can be complex breed and nutrition interactions (Kilpatrick and Steen 1999; Strydom *et al.*, 2000). It was observed in Uganda that the noted breeds (Ankole and Ng'anda) responded to supplementation by putting on weight even on limited level of feed supplement contrary to the Ankole-Friesian crossbreed that required high level of supplementation (Mpairwe *et al.*, 2003). Breed effect has also been reported by Mpiri (1994) that crossbreeding where increasing the percentage of *Bos taurus* genetic makeup, boosted the carcass weight in the Brahman and Sahiwal crosses. In a fattening trial, marbling decreased as the percentage of *Bos taurus* genetic make up increased (Strydom *et al.*, 2000). However, at maturity, the level of fattening was similar amongst all breed groups. Breeds with a smaller adult size and therefore with lower daily growth (early maturing), will be older and therefore have more fat than the larger and late maturing breeds if slaughtered at the same weight (Andersen *et al.* 2005). There are also breed difference in carcass muscle physical and biochemical properties (Notter *et al.*, 1991; Santos-Silva *et al.*, 2002).

Boran cattle have extensively been used in crossbreeding programmes and are considered as the most outstanding beef breed in East Africa (MLDF, 2009). Boran is a large framed cattle with good body conformation compared to TSHZ which are rather small framed and stocky animals. Earlier studies on growth performance of Boran cattle under feedlot condition, have reported an average daily gain (g/d) of 883 (Jepsen and Creek, 1976) and 1000 (Payne, 1990). In Tanzania, Luziga (2005), worked with Boran crossed with Ayrshire under feedlot condition and reported ADG of 1130 g/d. Similar results were also reported by Longino (2007). Diet composition and feeding manipulation strategies have also been shown to affect beef quality. Diets with low energy give rise to less tender meat compared with high energy diets when fed *ad libitum* (Kristensen *et al.*, 2002). It has been demonstrated that animals finished under feedlot condition tend to have higher dressing percentage, better carcass composition and better meat quality (Owens and Gardener, 2000). Creek and Squire (1976) reported ADG of 990 g/d for unimproved Boran and 1260 g/d for improved Boran using high energy molasses based diets under feedlot condition in Kenya.

It has been clearly demonstrated from the literature that there is a great potential in using the available feed and animal resource to produce quality beef through nutritional manipulation. The little information available in Tanzania indicates that Boran cattle under extensive ranch management can achieve an ADG of 250 to 400 g/d. A recent study by Mawona (2009) estimated ADG of TSHZ and Ankole fattened using agro-industrial by-products in Mwanza region to range from 440 to 780 g/d. It is not known, however, if the beef produced from such animals is of acceptable quality in the niche market that demand for such tender beef.

1.2 Problem Statement

Recent study by Mapunda (2007) indicated that there is an increasing demand for quality beef due to the emerging niche markets (high and middle class income earners, tourist hotels, mining areas and supermarkets) that prefer tender meat. In addition, changes in life style in towns have increased the demand for quality beef. Thus, there is great opportunity to improve the quantity and quality of beef and if this is coupled by reasonable increase in meat prices may revolutionise the beef value chain in Tanzania and therefore increase the income of livestock keepers. The MLDF (2009) noted that almost all the meat produced in Tanzania comes from cattle grazing on natural pastures. Cattle keepers normally sell animals in the market without finishing them. Only few farmers supplement their beef animals prior to sale (Mkonyi *et al.*, 2006; Mawona, 2009). This may imply that there is a need for research that will address the whole value chain of quality beef in Tanzania.

1.3 Justification of the study

Attempts made in Tanzania at Mtibwa Pilot Scheme for Production of Quality Beef using high energy diets based on either high molasses diets (37 % molasses + 19 % maize meal) or high corn diets (32 % maize meal + 27 % molasses) obtained similar ADG of 1.13 kg/day (Luziga, 2005). Such finding demonstrated that cheap feed resources like molasses can replace part of maize meal to produce quality beef. In a follow up of this pilot scheme, a project was set up to evaluate the opportunity of producing quality beef using the available feed and animal resources for increased income through improved market access and production of quality beef (Kimambo *et al.*, 2010). The projects main objective was to develop strategies on the use of available resources for production of quality beef under feedlot condition (Nandonde, 2008 and Mtaita, 2010).

Several studies have been conducted focusing on improving beef tenderness using other strategies apart from feeding and breed manipulations. These include pre-slaughter management and handling of animals and post-slaughter handling of carcasses and meat. Pre-slaughter management and handling of animals include age at slaughter (du Plessis and Hoffman, 2007; Schoonmaker *et al.*, 2002), sex manipulation by castration (Fiems *et al.*, 2003) and improved bleeding (Andersen *et al.*, 2005; Sanũdo *et al.*, 1998). Similarly, post-slaughter handling which includes carcass cooling (Morgan *et al.*, 2002), carcass suspension (Eskildsen *et al.*, 2010), meat ageing (Sentandreu *et al.*, 2002) and proper cooking (Jama *et al.*, 2007) can affect meat quality. However, there is limited information on what constitutes standard quality beef in Tanzania. Mushi *et al.* (2007)

reviewed some parameters indicative of meat quality such as meat tenderness, meat ultimate pH and meat colour. Tenderness has been reported to be one of the most important eating quality attributes, which influences the consumers overall judgment and perception of chewability of meat (Burke and Monahan, 2003).

Meat tenderness has been measured mainly by mechanical instrumental tests (e.g.Warner-Bratzler Shear Force) and by sensory panel test. The mechanical measurement which determines the meat resistance to shearing is the most common used method as sensory evaluation is very subjective (Christensen *et al.*, 2007). In Tanzania, very little information is available on the slaughter, carcass and meat attributes of the indigenous cattle. In addition, there is very limited information on how the indigenous cattle will respond to feeding manipulation under feedlot condition in order to produce quality beef that is acceptable to current domestic and export markets. There is also a need to develop feeding packages suitable for various strains of indigenous cattle in Tanzania.

The aim of the present study was therefore to evaluate the effects of two indigenous breeds of cattle (TSHZ and Boran) in Tanzania fed different diets under feedlot condition on performance, carcass and meat quality characteristics. The financial profitability of producing quality beef under feedlot condition is also assessed. The results of the present study will form the basis for recommendations of suitable production packages for quality beef.

1.4 Study Objectives

1.4.1 Overall Objective

To improve the quantity and quality of meat produced from indigenous cattle breeds in Tanzania

1.4.2 Specific Objectives

i. To evaluate the response of two indigenous cattle breeds fed different levels of finishing diet on weight gain, slaughter, carcass and meat quality characteristics
ii. To determine the effect of ageing time on tenderness of meat from the two cattle breeds and different finishing diets
iii. To assess the financial returns of feedlot enterprise using Tanzanian indigenous cattle and available feed resources.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview of Tanzania Beef Industry

Tanzania is rich in livestock resources in terms of number and diversity. The estimated cattle population is 19.1 million, ranking third in Africa, after Ethiopia (35 million) and Sudan (30 million) (ILRI, 2003; MLDF, 2009). In Tanzania, livestock production is an important sub-sector of agriculture contributing to about 30% of Gross Domestic Product (GDP) accruing from agriculture. It is also estimated to contribute 4.7% of the GDP. Njombe and Msanga (2009) reported that the contribution of beef sector to the GDP plays the biggest role of about 40% compared to other livestock products from the dairy sector (30%) and other livestock like small ruminants, pigs and poultry that contribute about 30%. It is also important to note that of all the beef consumed in Tanzania, the majority (98%) is produced from the traditional sector which constitute the indigenous cattle population (MLDF, 2009).

Despite this cattle population (19.1 million), the beef industry has not been exploited to the expected potential. According to Njombe and Msanga, (2009) a total of 218,976 metric tonnes of beef was produced in 2007/08. This amount of beef is rather small compared to Kenya which has about 13 million cattle and produced 288,909 metric tones in 2004/2005 (MPK, 2005) and Uganda which has about 11.4 million cattle produced 292,800 metric tonnes in 2004/2005 (FAO, 2005). Considering that these countries are of similar geographical location, there is every reason to suggest that animal productivity in Tanzania is low.

Various efforts have been initiated to change the production systems for improved productivity of beef in Tanzania. Over the years the National Ranching Company (NARCO) with its initial 15 ranches and a total land holding of 630. 000 ha. has remained to be the major commercial beef cattle producer in the country (MLDF, 2009). Apart from the government owned ranches, recently there have been some private investors and smallholder farmers who are engaging in ranching and feedlot business (Mawona, 2009). Other private feedlot investors as reported by Njombe and Msanga (2009) include Glienshils Ranch and Mtibwa Feedlot (Morogoro), Sumbawanga Agricultural and Animal Feeds Industries (SAAFI) in Rukwa, Manyara Ranch (Arusha) and Kisolanza Farm (Iringa). In addition, there are small scale livestock farmers in Arusha, Mwanza, Shinyanga and Mara regions who are either grazing and supplementing beef cattle or conducting small and medium scale feedlots (Mawona, 2009). Despite these efforts, however, these feedlot innovators are lacking information on appropriate feeding packages for fattening cattle under feed lot conditions and how various indigenous cattle breeds will respond when fed such diets. This may strongly suggest that there is a need for research to quantify such feeding packages based on sound scientific information.

Inadequate supply of quality beef from Tanzania in local beef markets cannot be disputed. This is evidenced by the amount of imported and exported meat including exportation of live animals during 2004/05 to 2007/08 as given in Table 1. The data indicated more imported meat than exported meat a situation that is not healthy for the growth of beef industry. To meet such demand for quality beef calls for value chain studies that will explore and document the possibility of producing, processing and marketing quality beef of acceptable consumers choice and preference for both the domestic and export markets.

Table 1: Import and export of meat and meat products (metric tons), and exportation of live animals as from 2004/05 to 2007/08

Item	Years			
	2004/05	2005/06	2006/07	2007/08
	Meat and meat products (metric tons)			
Import	1060	873	640	709
Export	-	4	92	195
	Exportation of live animals in numbers			
Cattle	4796	2542	1706	2772
Goats	1996	1852	800	874

Source: National Bureau of Statistics (2009)

In Tanzania, efforts to reduce the beef supply gap and increase income of livestock keepers' have been initiated by the Ministry of Livestock Development and Fisheries (MLDF) and other institutions aiming at improving the quantity and quality of beef from the indigenous cattle (Luziga, 2005; Mwilawa *et al.*, 2007; Madsen *et al.*, 2007). At Sokoine University of Agriculture (SUA), a major project is on going attempting to produce quality meat through market access and improved feed utilization (Kimambo *et al.*, 2010). Previous efforts were made between 1974 and 1986 at Kongwa and Mkata ranches through introduction of temperate beef breeds such as Hereford, Angus, South Devon, Limousin, Charolais, Simmental, Brahamn, Brown Swiss and Friesians for cross breeding with Boran. This programme showed promising returns although it was discontinued due to lack of finances and due to inconsistency in policy issues. In 1990, a programme in favour of using Boran and Boran x TSHZ as beef animal was introduced (Mpiri, 1990). This breeding programme was, however, carried out only under commercial beef ranches in Tanzania, [National Ranching Company (NARCO)] and therefore had little impact achieved in the productivity of the national indigenous cattle population under traditional sector (MLDF, 2009). Thus a need to extend such breeding programme to a national level for improved quality beef.

Breeding programmes and improved nutrition manipulation for production of quality beef interventions are possible if other resources are put in place. It is known that the beef industry in Tanzania is also characterized by poor slaughter houses, water supply and market access. Njombe and Msanga (2009) reported that there are few slaughter houses which are of accepted standards. These are the slaughter houses in Arusha (Sakina abattoir), Dodoma (Dodoma abattoir), Morogoro (Glienshils abattoir) and Sumbawanga (SAAFI abattoir). Recent report by MLDF (2009) indicated that there are other two modern abattoirs under construction at Ruvu in Coast Region and at Shinyanga town in Shinyanga region. Proper slaughter houses are necessary for production of quality beef acceptable in local and export markets.

2.2 Factors that Influence Quantity and Quality Beef

Various factors have been reported to influence increased production of quantity and quality beef (FAO, 2005). Njombe and Msanga, (2009) indicated various factors that constrain productivity of the beef industry in Tanzania to include low genetic potential of the indigenous cattle, inadequate infrastructure, inefficient marketing system, prevalence of animal diseases, poor technical support services and weak livestock farmers' organizations. The type of production systems that exist in the agro-pastoral and pastoral areas in Tanzania and elsewhere in East and Central African countries is miraged by many problems accounting to low beef productivity (Otte and Chilonda, 2002; ILRI, 2003).

Das and Mkonyi, (2003) indicated that low genetic potential of the indigenous cattle contributes significantly to low livestock productivity. For example, the Tanzania Shorthorn Zebu (TSHZ) cattle are rather small framed and stocky animal, characterized by low productivity (Mpiri, 1994, Njombe and Msanga, 2009). Similar views were decribed by Kurwijila and Kifaro (2001); Mwatawala and Kifaro (2001) and Das (2009). Such poor characteristics lead to low productivity of the beef industry. Comparing performances indices of Tanzania cattle with other performances elsewhere, Trail *et al.* (2010) reported higher reproductive performance indices of calving rate (71 and 85%), low mortality rate (11 and 7%) and high mature weight (270 and 284 kg at 2 years) for Africander and Tuli respectively in South Africa. Similar high reproduction and production performance was observed in Botswana with Simmental xTswana and Brahman xTswana crosses under intensive beef production system (Trail *et al.*, 2010). The authors concluded that proper crossbreeding and selection of the right strain among the indigenous cattle improves the performance of the beef industry producing carcass of the right size. This conviction could also apply to Tanzania conditions both in short and long term breeding programmes.

The beef industry in Tanzania is further constrained by poor nutrition which is contributed by inefficient utilization of the available feed resources (Nandonde, 2008) coupled with seasonal variation of feedstuffs in both quantity and quality (Doto *et al.*, 2004). In most cases animals depend on communal grazing during the rain season and crop residues/by products during the dry season. Such a situation leads to low productivity even when cattle of high genetic potential for beef production are used. Recent work by Nandonde (2008) reported on the surplus quantity of concentrate feeds available in Tanzania that could be used to improve nutrition of animals particularly under feedlot conditions. Among the potential available feeds include maize grain (62,000 tonnes), maize bran (565,944 tonnes) and rice polishing 88,800 tonnes) distributed in few regions of Tanzania which do not necessarily coincide with regions of higher livestock concentration. This has many implications in initiating feedlot as a business. A decision must be made either to move the animals to areas where feeds are available or move feeds to areas where animals are available. Such decision, however, must be based on sound economic principles. Tanzania is endowed with ample land that provides forage resource base. Njombe and Msanga (2009) noted that out of the total 88.6 million ha of land resource, 60 million ha are rangelands suitable for livestock grazing, able to carry up to 20 million Tropical Livestock Units (TLU) where 1 TLU = 250 kg liveweight as reported by Chilonda and Otte, (2006). However, due to tsetse infestation and other constraints, only 40% of the rangelands is utilised for grazing cattle, goats and sheep under extensive system. This area is inadequate for grazing animal population and is poorly utilized leading to overgrazing and land degradation thus low productivity.

It is well documented that the pastoral and agro-pastoral production systems are characterized by low productivity. FAO (2005) indicated that mature cows weigh 230 kg and mature bulls weigh 322 kg in semi-arid areas under pastoral production while mature cows weigh 246 kg and mature bull weigh 326 kg under agro-pastoral production at 6 years of age. In the tropics animals have low growth rate and sometimes loose weight during the dry season. The extent of loss, however, is depending on the severity of the drought (ILRI, 2003). Likewise, in the rain season, the animals may gain weight depending on the available grazing land and this gain may range from 450 - 710 g/d but this gain is for a short duration (ILRI, 2003). In Tanzania, cattle from traditional production system that are taken to the market are of low live weights. Das (2009) estimated that on average the mature weight of cows and bulls is 220 and 290 kg when cattle are brought for sale in primary and secondary markets. The low mature weight could be due to poor nutrition brought about by chronic overstocking on already denuded feed resources. On other hand Mwilawa (2004), argued that there is a need to evaluate and develop alternative beef livestock production systems that can result in improving efficiency and profitability. This is because open rangelands which have been supporting large numbers of cattle are now diminishing due to increasing human population and increasing demand for use of these open rangelands for crop production. Such factors have been conceptualized in Fig.1.

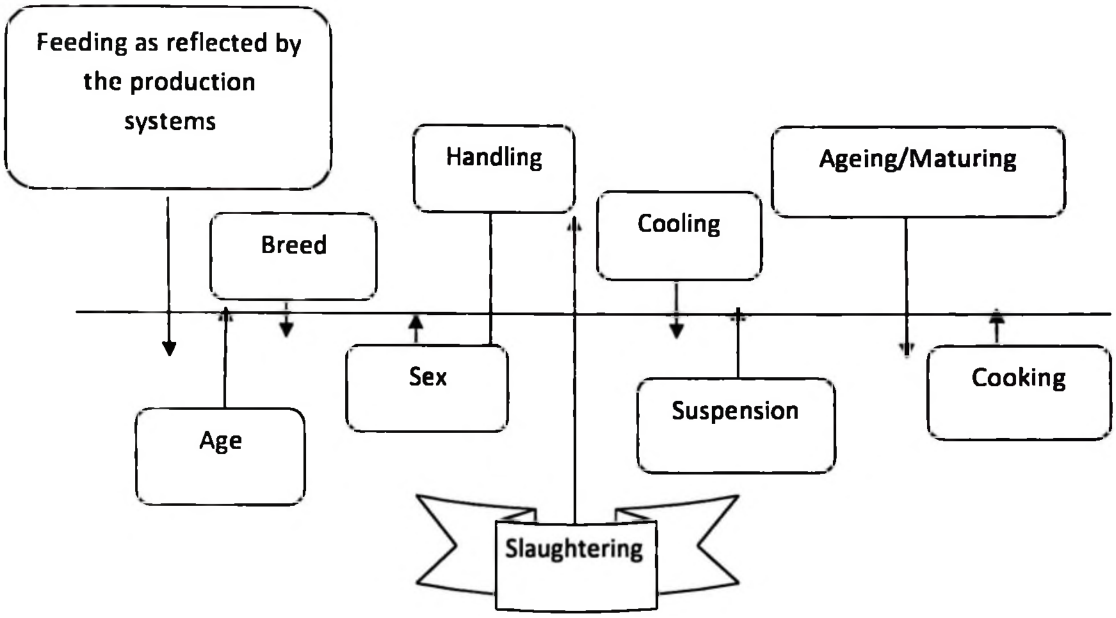


Figure 1: Factors affecting quantity and quality of beef

As indicated in Fig. 1, they are quite interrelated in the whole production value chain for production of quality beef. These include the beef production systems (Njombe and Msanga 2009), breed (Andersen *et al.*, 2005b), sex (Sañudo *et al.*, 1998) and age (Jeremiah *et al.*, 1998). Others are nutrition (Andersen *et al.*, 2005a), period in and time to stay in feedlot (Schoonmaker *et al.*, 2002), transportation of animals to slaughter house (Simmons *et al.*, 1997), slaughtering techniques (Anderson *et al.*, 2005b; Wood *et al.*, 1999), handling of carcass after slaughter (Strydom *et al.*, 2005; Sentandreu *et al.*, 2002), ageing of meat (Savell *et al.*, 2005) and processing of meat (Hwang and Thompson, 2001).

The factors, alone and in combination affect meat quality in complex ways and it is not possible to review all these factors and their interactions in this chapter. The review will therefore be limited to effects caused by the beef production systems, nutrition, breed sex, age, liveweight and/ or age of animals at entry and period of stay in feedlot and ageing. Possible areas of practical interventions and the financial analysis of finishing cattle under feedlot condition are also reviewed.

2.3.1 Beef production systems

Beef production systems vary from primitive to relative advanced system and have great influence to the quantity and quality of beef produced. In Tanzania, beef production system falls within the major livestock production systems which have been grouped into traditional and small-scale commercial production systems (Njombe and Msanga, 2009). The traditional systems include the pastoral, agro-pastoral and mixed crop-livestock systems. In broad sense the production system have been described to be extensive, semi-intensive and intensive production systems (MAFS, 2003).

2.3.1.1 Extensive system

Extensive system include traditional (pastoral and agro-pastoral) and commercial ranches. The traditional livestock keeping system under pastoral is characterized by long migration opportunistic, flexibility and risk spreading while searching for pasture and water. Under pastoral production system, animals depend on natural pasture which fluctuates in quantity and quality with season and thus availability of feeds is not certain. Under such situation Mwatawala and Kifaro (2001) reported that growth rate of animals is low attaining mature weight of 235 to 260 kg for cows and 260 to 285 kg for bulls during the dry season and 250 to 295 for cows and 270 to 320 kg for bulls during the wet season. It is likely that the indigenous cattle available in Tanzania cannot be blamed for their low performance as their genetic potential has not been fully exploited. According to MLDF (2009), commercial ranches in Tanzania are grouped under extensive beef production system where animals depend mainly on natural and little improved pastures. Supplementation is rarely done and may consider particular herd category, for example sick animals and milking animals. Although, the ranches in Tanzania have been put under extensive systems, the productivity in these ranches is much higher than in communally grazing areas due to some management improvements practices like improved pastures, deworming, disease control and use of breeds of larger frames like Boran (Mpiri, 1991).

2.3.1.2 Semi-intensive system

The indigenous cattle breeds have also been raised under semi-intensive systems with better expression of their genetic potential than when raised under extensive system. Cattle in this system are normally grazed and finished either on good pastures or have access to concentrate supplemention. It is commonly practiced in most agropastoral production system where harvested crop residues are conserved and fed to beef animals prior to market or taken for slaughter. The practice is also common in most commercial ranches (MAFS, 2003). In such ranches animals graze on pasture and supplementary feeds such as conserved forages (hay) and crop residues. Under commercial ranches therefore, animals perform better than any other systems under semi-intensive system. Mpiri (1991) reported mature weight of 256 kg for cows and 345 kg for bulls for the indigenous cattle when raised under NARCO condition.

Other systems, like agropastoral where semi-intensive system is practiced (MAFS, 2003); the system is less efficient since animals usually take long time to reach maturity. Mpiri, (1991) reported that under this system the off-take rate is low 8 to 23% which is higher than that of extensive system (6.5 to 10%) and lower than expected standard of 40-50% (MLDF, 2009). It is therefore, viewed that, under good animal management with optimal supplementation the semi-intensive system may give cost effective result in terms of increasing quantity and quality beef.

2.3.1.3 Intensive production system

This system entails confinement of animals in most of the time and feed is usually brought to the animals. Cattle are either reared and fattened for their whole life out in the field on pasture, or managed at some stage of their life under confinement (Payne, 1990). The system is characterized by high inputs and market oriented. The economics of intensive production depend upon, among other factors, type of cattle available, the level of management and use of least cost concentrates that will give quality beef, at acceptable price locally and export markets. Such system, need to be a commercial oriented production system. Feedlot finishing are known world wide to meet such a condition.

Intensive system under feedlot condition is mostly applicable when beef animals are to be fattened or finished for specific markets. In most cases, animals may be confined under constructed buildings. There is intensive utilization of agricultural by-products and other related commercial fattening feeds. The greatest advantages of feedlots are effective conversion of the feeds used, control of cattle movement and therefore little damage to livestock environment impact.

Animals finished under feedlot condition, have shown to increase muscle turnover and content of intramuscular fat and thus improve meat tenderness and juiciness (Webb and O'Neill, 2008). In addition the system allows considerable increase in efficiency of gain, slaughter weight and significantly increase the dressing percentage from 45% to 60% (Annet, 2005). Feedlot practice have further shown to increase efficiency of quality beef production, adding carcass value and increasing the return to investment when the feed resources are abundant and purchased at relatively low costs. However, very often such system requires animals with high genetic ability to economically convert feeds into gain. In Tanzania feedlot system has been practiced at Mtibwa Sugar (Luziga, 2005) in

Morogoro region with ADG of 1130 g/day using Boran crosses. Other small feedlot enterprises also have been reported to practice fattening in Mwanza and Shinyanga regions (Mawona, 2009), although the quality of the beef produced has not been evalutated.

2.3.2 Nutrition effects on quantity and quality of beef

Nutrition of beef cattle is by far the most important and pertinent factor for increased quantity and quality of beef. Among the components that are considered in the nutrition of beef cattle are type of feeds and availability, their combination and feeding strategies based on the animal's requirements that will result into increased quantity of acceptable beef quality with high consideration on health issues to the consumers.

2.3.2.1 Availability of feed resources

There are various feed resources which are used in beef production particularly under feedlot condition. These feeds are mainly grouped into roughages and concentrates. Likewise, minerals and vitamins supply are also important for a successful beef production. According to McDonald *et al.* (2002) the quality of the feeds is determined by nutrients concentration, digestibility and intake. In beef production, the most important nutritional aspects that have significant influence to increased quantity and quality of beef are the energy and protein value of the feed (Weisbjerg *et al.*, 2007).

Feed resources available for possible use in fattening cattle under feedlot conditions in Tanzania have extensively been reviewed and studied recently by Nandonde (2008) and Mtaita (2010). Such feeds include energy sources such as rice-polishing, wheat-bran, wheat-pollard, molasses, maize grain and maize bran, whereas protein sources are mainly sunflower seedcake and cotton seedcake. Osuji, (1999) reported that roughages are the cheapest and natural feed for cattle that are used to optimize protein and energy intake and to reduce the incidence of digestive disorders. Although the amount of roughages produced in Tanzania has not been accurately documented, Kimambo *et al.* (2004) reported that some natural pastures and crop residues, which could be used as animal feed, are wasted in the fields. This is because roughages are burned and there is also poor forage harvesting and conservation (hay and silage). These roughages forages available usually are low in energy and protein concentration (Doto *et al.*, 2004) to make up the whole ration for beef production. However, roughages are extremely necessary for providing physical structure for maintaining a healthy rumen. Concentrates are feeds of low crude fibre (less than 20% CF) and high in total digestible nutrients, however, different concentrates have different nutritive values which make them to differ in quality. The nutrients concentrations for the local feeds have been tabulated by Laswai *et al.* (2000) and Doto *et al.* (2004) and could be used to guide in estimation of chemical composition of various feedstuffs for ration formulations.

2.3.2.2 Available energy concentrates

Energy and protein concentrates are available feed resources and important particularly for feedlot animals. Some of the potential typical feeds for use in feedlots, their chemical composition, digestibility and energy value are presented in Table 2 (Van Soest, 1994; Doto *et al.*, 2004 and Sauvant *et al.*, 2004). Maize grain is one of the best energy dense feedstuff with ME 13.6 MJ/kg DM and is widely used in feedlot ration (Andersen *et al.*, 2005b; Sauvant *et al.*, 2004). However its major limitation as feed for cattle has been its competition with human particularly in developing countries where maize forms the main staple diet of the people (FAO, 2005).

Table 2: Potential concentrates feeds for use in feedlot and their chemical composition

		DM (%)	Ash	% of dry matter Crude protein	Crude fat	NDF	Ca	P	OM	ME
Concentrates										
Molasses	Cane	73	14	5.5	0.4	0	5.4	0.7	86	9.8
Grain	Maize meal	92	1.4	12	5.5	10	0.2	3.6	92	14
Bran	Maize	88	4.6	12	3.5	26	0.5	6.2	73	11
	Rice	90	11	11	8.7	28	0.8	16.	89	13
	Wheat	87	5.8	18	4.6	38	1.1	12	71	11
Oilseed cake										
Cotton seed decorticated		92	7.3	52	3.5	25	2.2	12	80	13
Cotton seed uncorticated		92	5.3	28	6.6	47	2.2	12.	58	9.8
Sunflower		92	6.4	33	11	38	3.9	9.6	69	12
Sunflower fat rich		92	5.7	29	22	34	3.5	8.6	72	14
Soybean meal		88	5.8	43	9.4	12	2.7	6.2	89	15
Unconventional feeds										
Cassava meal		87	5.1	3.0	1.0	7.0	0.5	1.2	91	12

DM = dry matter; OM = Organic matter (Digestibility (%)); ME = Energy (MJ/kg DM)
Source: Weisbjerg *et al.* (2007)

Brans from various sources such as rice, maize and wheat (Table 3) can form a source of feed for fattening animals. Brans are generally higher in crude protein, and fibre with low to medium energy concentration than the grains. However, brans just like grains are generally low in calcium but has medium to high phosphorous concentration (Weisbjerg *et al.*, 2007) When fed in combination with molasses it can form an ideal fattening diet. Molasses can also be fed in high amounts to beef animals without causing health problems such as acidosis (Bailey *et al.*, 2004).

Molasses is another important locally available agro-industry by products used in feedlot rations as reported by various authors (Preston and Wills, 1974; Annet, 2005; MLA, 2006; Nandonde, 2008). In addition molasses is very popular for draught feeding and is also used as a carrier for protein and mineral supplements (MLA, 2006). Molasses contains approximately 10.3 MJ ME per kg DM making it an excellent source of dietary energy. As a rough guide, molasses is often the cheapest source of energy. Molasses is tasty, and therefore can improve palatability of a ration and have its ability to bind dusty foods. Sugar often affects rumen metabolism towards more propionic acid pathway. In addition molasses which favour fattening contains many minerals that are important for optimum animal health and performance. Molasses is high in potassium, sulphur, iron and manganese and contains many other essential minerals (MLA, 2006; Weisbjerg *et al.*, 2007).

Under feedlot conditions, molasses-based diet achieved live-weight gains of more than 1400g/day when molasses constitutes 45-60 per cent of the animals' diet. The study also found that replacing feed barley or maize with 29 to 50 % molasses had no effect on meat eating quality, tenderness or meat and subcutaneous fat colour (MLA, 2006). Molasses has been promoted for feedlot animals in Tanzania due to its easiness in availability in some of the sugar industry in the country like Mtibwa, Kilombero, Kagera and Moshi (Arusha chini). The factories are far from where livestock are available suggesting that consideration should be given to transportation costs of molasses (Aneth, 2005; Madsen, 2005).

2.3.2.3 Available protein concentrates

In Tanzania, oil seed plants produce inevitable agro-industrial by-products which are important as plant proteins for animals, major ones being cotton and sunflower seed cakes. Fat content vary highly according to the facilities used for oil extraction, and can be above 20 % of DM for on farm ram pressed sunflower cake (Weisbjerg *et al.*, 2007).

Other protein sources known are soy bean cake which is a high protein and high energy concentrate, less dependent on decortication than cottonseed and sunflower as soy fibre are highly digestible. Generally, oilseed cakes and meals are low in calcium and medium to high in phosphorous (Weisbjerg *et al.*, 2007).

Where nitrogen is limited, like the case of molasses, the feedstuff of choice is urea the fertilizer or animal grade. Urea is non-protenous nitrogen (NPN) ingredient which can be incorporated in most feedlot diets. Various studies have reported that urea is physically easy to feed (Magalhães *et al.*, 2006). However, urea can be toxic when used in excess, and inexperienced operators should not attempt to use more than 1% in their ration (Barajas and Zinn, 1998). Urea is used to stimulate the intake of high concentrates diets because when molasses is used the energy pool in the rumen is utilised to synthesise microbial protein from NPN, thus minimising the chances for acidosis that would have occurred when using high levels of molasses (Cooper *et al.*, 1999; Bailey *et al.*, 2004). However, the recommended level of urea supplementation should not exceed 13-23 g/day per cow (Magalhães *et al.*, 2006). This is to ensure the rumen microbes have adequate NPN supply to utilise the energy from molasses that is degraded at the same rate in the rumen (Mgheni *et al.*, 1994).

2.3.2.4 Available roughages

The main roughages available for feedlot feeding are straw, stover and hay. These forages are all too low in energy concentration to make up the whole ration in a feedlot; however, forages are necessary for providing physical structure for maintaining a healthy rumen. Some typical feed values for the three forage types are given in Table 3 (Doto *et al.*, 2004; Van Soest, 1994). Some forage like maize silage have the potential for an energy concentration high enough to make up most of the ration, and could be an option if the local situation allow for cultivation of maize in large scale, or competitive cultivation of other energy dense forages. An alternative to total feedlot might be day-time grazing if good pasture is available, and feedlot feeding at night-time, feeding concentrate when the cattle return to the feedlot in the evening and before leaving for pasture in the morning.

Table 3: Potential roughages for use in feedlot and their chemical composition

Forages		DM (%)	% of dry matter Ash	Crude protein	Crude fat	NDF	Ca	P	OM	ME
Stover	Maize	85	7.1	8.1	1.3	75	3.8	2.0	69	9.2
Straw	Rice	85	16	5.5	1.9	76	3.0	1.4	48	6.0
	Wheat	85	3.1	3.3	1.9	82	3.6	0.9	44	6.2
Silage	Grass	20-40	9.2	13	4.0	56	5.1	2.9	63	9.0

DM = dry matter; OM = Organic matter (Digestibility (%)); ME = Energy (MJ/kg DM)

2.3.2.5 Grazing and grain feeding

Beef is produced either extensively from pastures or semi-intensively or intensively in feedlots. In Tanzania majority of cattle are finished from pastures and the meat is generally tough. In general, carcasses from feedlot-fed cattle are heavier and contain more fat than carcasses from forage-fed cattle (du Plessis, 2007). Hale *et al.* (1998) reported that, neither natural pastures nor improved tropical pastures, meet the nutritional requirements of ruminants for optimum production. The main limitation reported by these authors and others was the low availability of forages and associated low nutritive value during the dry season (Whiteman, 1985). The growth performance of cattle on pasture, either native pastures at low stocking rates or improved pastures at higher stocking rates, seldom exceeds 1000 g/day and maximum growth occurring during the wet season and at low stocking rates (Whiteman, 1985). Hence, finishing cattle on pasture could relatively be cheap but may limit the increase in quantity and quality of beef.

2.3.2.6 Feeding manipulation for production of quality beef

Animals under feedlot can be victims of urea, molasses toxicity and/or acidosis if the feeding manipulation is not well planned. The objective of feedlot is to feed high energy diets so that the animals attain fast ADG and achieve slaughter weights at the shortest possible time. Forstrer (2005) reported that cereal grain is the principal source of energy in diets of feedlot cattle in many parts of America where finishing diets which will give satisfactory weight gains at minimum health risk is recommended to be composed of 75:25 to 80:20 grain to roughage ratio. Cheng *et al.*, (1998) was of the opinion that grain to roughage ratio can vary from 50:50 to 90:10 depending on the cost and how animals are gradually accustomed to the diet. An illustration is presented using the following table that show calculated ME that steers must be fed on daily basis for most Central African countries for steers kept on intensive and extensive production systems (Table 4).

Table 4: Calculated ME for daily feeding of steers in most Central African countries

Variable	Liveweight of steer (kg)				
	400	400	300	200	150
Rate of growth (kg/day)	1.25	1	1	1	1
Energy Concentration in Diet (MJ/kg)	10.5	10.5	10.5	10.5	10.5
Energy value of gain (MJ/kg)*	20.9	20.9	16.7	12.5	12.5
Energy Retention above maintenance (MJ ME)	26.1	20.9	16.7	12.5	12.5
Required to eat for production ((MJ ME) /day *	60.2	48.2	39	28.6	28.6
Required for maintenance (MJ ME) /day – *Int.* *	44.7	44.7	35.6	26.5	22
Required for maintenance (MJ ME)/day – *Ext.* *	53.6	53.6	42.7	31.8	26.4
Total dietary required (MJ ME) /day –*Int.*	104.9	92.9	74.6	55.1	50.6
Total dietary required (MJ ME) /day– *Ext.*	113.8	101.8	81.7	60.4	55

Int. = Intensive; Ext. = Extensive

* Source: Topps and Oliver (1993)

2.3.2.7 Nutrient requirements of Beef cattle

Understanding the nutrient requirement of beef cattle will guide the level of nutrition particularly energy level to be provided from the diet. According to AFRC (2003), the performance of growing and finishing cattle is largely determined by voluntary feed intake, (VFI) so that manipulation of proportion of concentrate to achieve a certain target rate of live weight gains is critical. The energy value for gains in cattle, usually vary widely between 10 ME MJ/kg of gain for young weaned bulls to 30 ME MJ/kg of gain for finishing heifers of over 400 kg liveweight (Allen, 1992). The major reason for this variation is due to differences in laying fat. As the rate of depositing fat increases with age it requires more energy per unit gain compared with lean since fat has double the energy concentration compared to protein (McDonald *et al.*, 2002) which is the main content of muscles. Similarly, the muscle to bone ratio is known to vary with breed and sex of animal where the protein content of the gain varies from 140 to 170 g/kg of gain (Allen, 1992) and 120 to 140 g/kg of gain (Topps and Oliver, 1993). NRC (2003) have tabulated guideline while formulating rations, where quadratic equations have been made to predict the energy value and protein of weight gains and suggested breed category into early, medium and late maturing categories. Table 5 gives examples of the tabulated ME (MJ/d) and metabolizable protein (MP) in g/d requirements that could be used to estimate the gain while formulating rations.

According to NRC (2003) an indication of frame size is very important when estimating growing and finishing cattle nutrient requirements and projected VFI. Although larger framed cattle will generally have increased VFI, energy concentration in the feed that is used for gain (NEg) is lower than that of medium framed cattle. Furthermore, protein requirements for large framed steers have been based on requirements of medium framed steers that weigh 15% less, thus leading to serious under estimation of protein requirement for large framed cattle. Herd *et al.* (2003) and Schenkel *et al.* (2004) reported variation in VFI based on animal size, growth rate and composition of gain. Various authors (Topps and Oliver, 1993; NRC, 2003) have published on nutrient requirements for beef cattle. An example of the nutrient requirement is given in Table 5 considering liveweight of the animal, maximum VFI, ME requirements and metabolizable protein (MP) requirements in the diet. It is evident from Table 5 that higher growth rate requires more energy and protein per kilogram gain at the same liveweight.

Table 5: Energy (ME MJ/d) and Protein (MP g/d) requirements of feedlot bulls of the late maturing breeds (100 – 300 kg liveweight)

ADG	Liveweight = 100			Liveweight = 200			Liveweight = 300		
(kg/d)	DMI (kg)	ME (MJ)	MP (g)	DMI (kg)	ME (MJ)	MP (g)	DMI (kg)	ME (MJ)	MP (g)
			Energy value = 11 MEMJ/kg						
0.5	2.4	26	249	3.7	41	288	4.9	54	324
0.75	2.7	30	328	4.2	46	360	5.5	61	392
1	3.2	35	402	4.8	53	429	6.2	69	456
			Energy value = 12 ME MJ/kg						
0.5	2.1	25	249	3.3	39	288	4.3	52	324
0.75	2.4	29	328	3.7	44	360	4.8	58	392
1	2.8	36	402	4.2	50	429	5.5	66	456
1.25	3.2	38	471	4.7	57	492	6.2	74	515
			Energy value = 13 ME MJ/kg						
0.5	1.9	24	249	2.9	38	288	3.9	50	324
0.75	2.1	28	328	3.3	43	360	4.3	56	392
1	2.4	32	402	3.7	48	429	4.8	63	456
1.25	2.8	36	471	4.2	54	492	5.4	71	515

Source: ARC, 2003

2.3.2.8 Formulation of cost effective diet

Potential feeds can be scarce in supply and expensive for formulating cost effective diet for quality beef production. Therefore it is important to consider alternative feed combinations. . Rations composed of roughages have low energy concentration values, which may range from 7.5 to 8.5 MJ/kg DM while energy rich-concentrates have high energy concentration values that range from 12.5 to 13.5 MJ/kg DM (Topps and Olive, 1993; NRC, 2003). Thus when beef animals are fed roughages or grazed only, it can be cheap but the diet will not have enough energy concentration. In Tanzania, feedlot rations could be formulated based on locally available feeds.

Weisbjerg *et al.* (2007) gave examples of ration compositions which could supply feedlot cattle with sufficient energy and other nutrients to obtain a high growth rate if fed *ad libitum.*

He emphasized that, undersupply of protein and calcium, and oversupply of fat in feed ration need to be avoided, whereas oversupply with protein and minerals have minimal effect to production (Weisbjerg *et al.*, 2007). On other hand, oversupply with energy (lack of structure in total ration) could cause problems. It is obvious that the animals need a certain minimum amount of fibrous feed to avoid health problems like acidosis as reported by other workers (Magalhães *et al.*, 2006; Weisbjerg *et al.*, 2007), and this has to be monitored closely when aiming at maximum feed intake and weight gain. In formulating feedlot feeds, there is therefore the need to take into considerations the availability, and nutritive value of the feeds and their accessibility of the feeds throughout the feedlot period.

The quantity and quality of food which animals eat is considered to be one of the most important factors that affect the productivity and profitability of livestock enterprise. The beef animal requires proper and adequate feeding of energy, protein, minerals and vitamins to meet both maintenance and production (McDonald *et al.*, 2002). Important minerals and vitamins to consider when formulating a feedlot ration include phosphorus, calcium, sulphur, potassium, sodium, vitamin A and E and other trace elements, where as in some instances it is necessary to add 0.1 to 0.5% salt to feedlot diets to meet sodium requirements (Forstrer, 2005a; 2005b). Nevertheless, the most important nutrition limitations to production are simply energy and protein (NRC, 2003). Norris *et al.* (2002) reported that feed is the major single cost item among the variable costs in a feedlot enterprise and it can cost over 70% of the production costs. Thus thorough consideration need to be given in recommending proper feeding standards, duration of finish, costs for feeds and type of animals, such that feedlotters attain reasonable economic returns (Madsen *et al.*, 2004). Feedlot animals are introduced to grain diet gradually, increasing the amount of grain and decreasing the amount of roughage. Currently, full concentrate diet with no roughage in feedloting is rare and generally not recommended. In Tanzania, no feeding standard is available that could be usedfor feeding feedlot animals. However, Tanzania feedstuff table (Doto *et al.*, 2004) have been prepared and can be used for formulating diets.

2.3.3 Breed effects on meat quantity and quality attributes

Various authors have demonstrated the effect of breed on beef quality attributes (Table 6). The variation is great in all the parameters given (Table 6).

Table 6: Slaughter weight, muscle percentage and toughness for different breeds

Breed	Age	Frame size	Slaughter wt (kg)	Muscle (%)	Tenderness (N)	Reference
Boran	3 y	*medium*	310	52	-	Mpiri, 1994
TSHZ	4 y	*small*	270	51	-	Mwatawala, 2001
S.Holstein	7 m	*large*	505	58	32	Monsóon, *et al.*, (2004)
B.Swiss	7 m	*large*	550	62	29	Monsóon, *et al.*, (2004)
Limousin	7 m	*large*	561	68	26	Monsóon, *et al.*, (2004)
B.d'Aquitain	7 m	*large*	617	74	27	Monsóon, *et al.*, (2004)
Bonsmara		*med-large*	467	73	58	Frylinck *et al.*, (2006)
Tuli		*Med-large*	418	73	57	Frylinck *et al.*, (2006)
Nguni		*medium*	324	54	61	Frylinck *et al.*, (2006)
Belgium Blue bulls		*large*	688	70	-	De Sonet *et al.*, (2000)

It is evident that breed have significant impact on increased meat yield. Table 7 indicate that breeds like Spanish Holstein, Brown Swiss and Limousin, although they are of young age but have higher slaughter weight and more meat yield percentage compared to Boran and TSHZ. Similar information were reported by Du Plessis and Hoffman (2007) who indicated that larger frame-sized is associated with greater growth potential, longer finishing periods and heavier slaughter weight when compared to small framed breed under the same feeding regime. In US, Dhuyvetter, (1995) found that large frame steers and heifers produce choice carcasses only when their live weight exceeds 544 and 454 kg, respectively. Medium frame cattle are expected to produce choice carcasses at live weights of 454 to 544 kg for steers and 363 to 454 kg for heifers. Small frame steers and heifers would produce choice carcasses at live weights of less than 454 and 363 kg, respectively. Thus liveweight that correspond to a given carcass grade is a function of mature size and hence indirectly reflecting the frame-size of the animal. It is evident therefore that TSHZ, which has small frame-size will produce small carcasses and of low grade.

Growth rate measured as an average daily gain (ADG) has also been reported to be influenced by breeds. Frylinck *et al.* (2006) indicated that reasons for differences in ADG performance between breeds could be a function of genetic potential and stage of physiological maturity. Hornick *et al.* (1998) working with Beligian Blue bulls, which are large beef breed and of early maturity, found a high ADG (1320 g/d) when finished under feedlot condition. In US, significant breed differences on ADG for *Bos taurus* cattle have been reported to been 1300, 1270 and 1260 g/d for Angus, Brahman and Hereford respectively. These values were higher than values of 1020 and 970 g/d found of *Bos indicus* cattle of Boran and Tuli respectively fed high concentrate diet (Ferrell and Jenkins, 1998).

Animals with large body frame, however, have high maintenance requirements but their high growth potential and their efficiency for energy use for gain; give carcass which can yield preferred table carcass cuts (Schoonmaker *et al.*, 2002). This implies that these animals are the best candidates for beef production under feedlot condition. The only pertinent question is will the breed be adaptable to the tropical condition when imported to Tanzania since they are not indigenous to Tanzania?

Breed differences on meat quality have well been reported with muscles from *Bos taurus* being tenderer than muscles from *Bos indicus* cattle. Studies by Shackelford *et al.* (1994) and Wulf *et al.* (2002) suggested that genetic differences in beef tenderness were associated with variation in the rate and extent of muscle proteolysis that occurs during post-mortem storage of fresh beef. This is because the calpastatin activity which consists of two calcium-requiring enzymes, (μ-calpain and *m*-calpain), and an inhibitor (calpastatin), is believed to be the primary proteolytic enzyme system involved in post-mortem tenderization of the aged beef. A study by Andersen *et al.* (2005a) have indicated that calpastatin activity, measured at 24-h post-mortem, have been implicated in causing tenderness differences in beef between *Bos taurus* and *Bos indicus* cattle. One of the possible causes for the difference in tenderness between *Bos indicus* and *Bos taurus* breed crosses was identified to be the calcium-dependent protease inhibitor which affects the fragmentation of myofibril, one of the important components that affect tenderness. Andersen *et al.* (2005a) also reported that the breed difference in eating quality between *Bos indicus* and *Bos taurus* was associated with in vivo differences in muscle protein turnover, being lower in the *Bos indicus* than *Bos taurus*.

The quality of beef has also been reported to be influenced by breed on deposition of fat under feedlot conditions (Notter *et al.*, 1991). The difference has been shown to be associated with muscle physical and biochemical properties in the carcass (Santos-Silva *et al.*, 2002). The increase in weight coupled with laying down a layer of fat has a significant effect in increasing the market value of the meat. Webb and O'Neil, (2008) indicated that such attributes have a significant contribution to meat flavour, juiciness and tenderness. Notter *et al.* (1991) working with unimproved pastoral cattle, reported that it is possible to profitably increase the yield of edible carcass per animal by between 30 and 50% during 10 weeks in the feedlots. However parameters on meat quality attributes were not measured.

In Tanzania, beef quality attributes have not been measured either. Most parameters on the ADG and slaughter characteristics have been done in ranches and slaughter houses for grazing animals for indigenous cattle. Recent work (Mushi *et al.*, 2009a; Safari *et al.*,

2011) has reported on meat quality from supplemented goats and sheep which cannot compare well will cattle breeds. There is therefore the need for research that will assess the beef quality attributes important for production of quality beef (slaughter carcass and meat characteristics).

2.3.4 Sex effects on meat quantity and quality

The properties of a muscle is their visual appearance, physiological parameters or biochemical characteristics are a reflection of the proportions of types of muscle fibres present which most often is related to sex of the animal. Sex of the Animal has been considered to influence the acceptability of beef. Andersen *et al.* (2005a) reported that meat from bulls is usually less tender compared to meat from steers and this is due to the rate of proteolysis post-mortem in favour of steers. However, bulls have been reported to gain body weight more rapidly, and produce carcasses that have larger LD muscle area and yield heavier carcass with better conformation and better joints when compared to cows and steers (Fiems *et al.*, 2003). This may imply that bulls may be mostly preferred because the factors such as control of stress and other management factors that influence tenderness are easily controllable in developed countries. In the tropics, however, steers are preferred because these animals are readily available (Nandonde, 2008) as castration is a tool mostly used for breeding management in most tropical countries.

2.3.5 Effects of age on meat quantity and quality

Liveweight and carcass traits of economic importance are known to be influenced by the age of the animal. Within animal, ADG and the resultant carcass weight and components of the body increases exponentially with increase in age (Berg and Butterfield, 1976; Lawrence and Fowler, 1997; Andersen *et al.*, 2005b). Thereafter the liveweight and carcass weight increases at a decreasing rate so that at mature weight the asymptote of growth reaches zero (Hammond *et al.*, 1971; Therkildsen, *et al.*, 2004). The increase in dressing percentages merely reflect the differential rate of growth of the carcass and non carcass components, the carcass growing at faster rate and therefore increasing in dressing percentage (Hornick *et al.*, 1998). The carcass composition also changes with age with the proportion of fat increasing at fast and bone decreasing because these tissues are late and early maturing respectively (Berg and Butterfield, 1976; Therkildsen, *et al.*, 2004). Therefore decision to slaughter animals of given fatness and grade is entirely under mans manipulation.

Meat tenderness has been reported to be influenced by animals' chronological age. As the age increases, toughness increases mainly due to nature and concentration of connective tissues (Jeremiah *et al.*, 1998). Age of an animal influence the taste of meat consumed and young animals are more tender and less taste than older animals (Christensen *et al.*, 2007). This is because the protein breaking down enzyme system decreases as an animal gets older. So, paradoxically, aging the meat by leaving it to hang for some weeks works best with younger animals. Likewise, as animals gets older the amount of connective tissue (collagen) increases (Sañudo *et al.*, 1998). More importantly, the degree of interconnectivity of the collagen increases with age, which results in the collagen becoming resistant to dissolution in cooking. Thus, meat from older animals can become more resistant to tenderisation in cooking, and require longer, slower cooking, time in order to break the greater amount and connectivity of the collagen (FAO, 2005). Mushi *et al.* (2006) in his review reported that meat tenderness decrease with animal's chronological age and have reported increase in fibrousnesses with age. As also discussed early Msanga *et al.* (2001) ,also indicated that the degree of maturity affects the development of bone, muscle and fat tissues, where in young animals the growth rate of skeleton is high and as the animal ages, deeper muscling of the skeletal frame occurs. At latter stages, fat deposition under the skin (subcutaneous fat) and around the muscular carcass i.e. fat marbling. The toughness of meat is also attributed by the shortening of the distance between connective tissues and shortening of sarcomere length (Savell and Cross, 1988; Koohmaraie *et al.*, 2002). There is no information available on such data in Tanzania for indigenous herd of cattle.

2.3.6 Effects of age at entry and period of stay in the feedlot on yield and quantity of meat

Age at entry to the feedlot have been reported to have significant impact on response of the animal to nutrition in terms of ADG, slaughter weight, carcass weight and thus financial implication to the feedlot entrepreneurs. A study by Schoonmaker *et al.* (2002) indicated that earlier feedlot placement accelerates finishing and produces young, higher marbled beef, but with lower carcass weight. As feedlot entry age increases in animals, intramuscular fat deposition tend to be deposited very fast and may result to an overweight and over fat carcass. Schoonmaker *et al.* (2002) dealing with early weaned calves under feedlot condition found that average daily gains of 1.62, 1.47 and 1.21 kg/day and voluntary feed intake (VFI) of 7.1, 8.1 and 10.5 kg/day were observed when fed for 111, 202 and in 371 days respectively. Such a good response may imply that the growth rate decreases and VFI per day increases with increasing period of stay under feedlot. In this study carcass weight and LD muscle increased with length of stay at feedlot. This may imply that manipulation on the age of entry and days of stay in the feedlot can have impact on the quality of beef produced among the indigenous cattle in Tanzania.

2.4 Performance of Beef Cattle and Meat Quality Attributes

2.4.1 Growth performance

Improvement in quantity of beef have mainly been assessed through increased in average daily gain (ADG) while improvement in quality have mainly been on acceptance of the meat mainly through tenderness. The ADG (kg/d) is normally calculated from final liveweight (kg) of the animal minus the initial liveweight (kg) divide by duration of gain (day). Growth perfomance of beef cattle has been assessed by various workers using ADG parameters. Skunmum *et al.* (2002) improved average daily gain of beef breed from 707 g/d to 794 g/d with crossbreeding and from 623 g/d to 777 g/d under good nutrition. Improved nutrition and crossbreeding of Holstein-Friesian in different studies found that the ADG increased from 800 to above 1000 g/d (Nijthavorn, 1995; Skunmum *et al.*, 2002). Several studies under feedlot condition have been conducted in Africa aiming at improving the quantity and quality of beef produced using different breeds and diets (Table 7).

Table 7: Average daily gain (g/day) of different breeds fed various fattening diets

Breed	Type of feed	Average daily gain (g/day)	Reference (Country)
Boran Steers (10wks)	Maize grain (53%); Maize Silage (33%); Molasses (11%)	1000	Creek 1972 (Kenya)
Boran (10 wks) Arussi (10 wks)	Molasses (48.5%); Maize grain (8.6); Niger s'cake (21.7%) Eragrostis (20%)	883 581	Jepsen and Creek 1976 (Ethiopia)
Holstein –early weaned (179 dys)	Diet based on byproducts	1350	Meissner *et al.* (1995) (S. Africa)
Boran x Ayshire (107 dys)	Molasses (36%) Maize (19 %)	1360	Luziga. (2005) (Tanzania)
Boran x Ayshire (107 dys)	Molasses (27 %) Maize (32 %)	1170	Luziga. (2005) (Tanzania)
Nguni -communal farms (132)	Commercial feedlot diet	1330	Frylinck *et al.*(2006) (South Africa)
Nguni –emerging farmers (132)	Commercial feedlot diet	1510	Frylinck *et al.*(2006) (South Africa)
Brahaman – (132)	Commercial feedlot diet	1520	Frylinck *et al.*(2006) (South Africa)
Charolais	Commercial feedlot diet	2300	Strydom, (2008)
Charolais X Nguni	Commercial feedlot diet	1490	Strydom, (2008)
Western Sudan Bulls (56 dys)	Unprocessed sorghum + traditional concentrates 45%	1100	Mohammed *et al.* (2008) (Sudan)
Western Sudan Bulls (56dys)	Processed sorghum + traditional concentrates 100%	1430	Mohammed *et al.* (2008) (Sudan)

It is evident from these authors that breeds respond differently when fed different diets. The variations range from 581 g/d for Arussi cattle breed in Ethiopia (Jepsen and Creek, 1976) to 2300 g/d for Charolais breed under commercial feedlot diets in South Africa (Strydom, 2008). It is also important to note the variations in the proportion of different feeds in each diet and the variations shown by the animal response. This may imply that in fattening diets, there is a wide room for manipulation of the diet in order to achieve the target ADG that can give quality beef.

2.4.2 Slaughter and carcass chracteristics

Handling of animals for slaughter

Meat consumers are increasingly demanding that animals be reared, handled, transported and slaughtered using humane practices (Appleby and Hughes, 1997). Belk *et al.* (2002) characterized need for humane treatment of animals in slaughterhouses which includes unloading, lairaging, movements, stunning and bleeding of animals are important for animal welfare. Training and sensitivity of personnel are also essential.

It is therefore of public concern regarding the welfare of animals during transportation and handling which necessitates reduction in such stresses with aim of attaining the best quality meat. This view have earlier been recommended by FAO (2005) that animals should be stress free and injury free during operations prior to slaughter so as maintain muscle glycogen reserves, that may yield maximum level of lactic acid in meat, which will give meat ideal pH measured 24 h after slaughter.

Transportation of animals to slaughter

Poor transportation of animals for slaughter has serious deleterious effects on the welfare of livestock and can lead to significant loss of quality and production. The major effect of transport and movement is stress that can lead to dark firm and dry (DFD) in beef and pale soft exudative (PSE) in pork (Tarrant *et al.*, 1992; María *et al.*, 2003; Andersen *et al.*, 2005b). In cattle, transportation of less than 4 h has been reported to have no effect unless there is trauma (Grandin, 2000; Grandin, 2010). Tranportation of less than 12 h have been proposed by the Scientific Committee on Animal Health and Animal Welfare (SCAHAW), European Parliament has suggested decreasing journey to 8 h (Earley and O'Riordan, 2006), while Villarroel *et al.* (2003) indicated that 3 h transportation of bulls before slaughter give rise to optimal tenderness and acceptance of meat compared to 6 h of transportation. However, the proposed measures may improve animal welfare but it is not known whether it will improve the meat. A study by María *et al.* (2003) indicated that the percentage composition of the 6th rib muscle, fat and bone did not vary with transport time, except slight effect was observed on meat compression values. Similar observation (María, *et al.*, 2003) of no differences in tenderness of muscle after transport or handling stress, compared with controls. Under the controlled commercial conditions i.e .the same type of animal, same age, same production system, and the same vehicle and driver, it appears that transport time up to 6 h may not affect the instrumental quality of meat (María *et al.*, 2003). In other study mixed loads of cattle had a significantly higher frequency of dark-cutting in beef than unmixed loads (Belk *et al.*, 2002).

It is therefore important to take care in handling the animals to slaughter since getting animals from farm to abattoir forms the first link in the chain of meat production. It is important because it can influence carcass and lean meat quality, and it is contentious because the processes of handling and transport (Belk *et al.*, 2002) provide many opportunities for the animal's welfare to be compromised.

2.4.3 Slaughtering procedure

It is very important that slaughter animals should be properly well handled i.e restrained before stunning, hanging and or bleeding. This is to ensure stability of the animal so that the stunning operation can be carried out accurately and properly to give meat the desired quality (Grandin, 2000; Grandin, 2010). Effects of stress to animals before and during slaughter have been reported to have serious effect on meat quality (Simmons *et al.*, 1997; Mushi *et al.*, 2007). Reports from Andersen *et al.* (2005) and FAO, (2005) indicated that when animals are stressed the glycogen is used up and lactic acid level that is developed is reduced in the meat after slaughter resulting to DFD. This meat is of inferior quality due to less taste, darker, less acceptable to consumer and has a shorter shelf life due to abnormally high pH value (6.4-6.8). Various workers have reported that animals for slaughter should adequately be rested. Prior to slaughter, animals should be driven to the stunning area in a quite and orderly manner without undue fuss and noise, animals should not be beaten nor have their tails twisted (Mushi *et al.*, 2007; Grandin, 2010). Stunning aims to eliminate pain, discomfort and stress from the procedure.

Three main stunning methods have been used namely percussion, electrical and gas, where the first two are commonly used in developing countries. Percussion stunning method produces a physical shock to the brain e.g captive bolt while electrical stunning induces electroplectic shock or epileptic state in the brain. Once the animal is unconscious the animal is bled using a sharp knife to cut the throat and severe the main blood vessel (Grandin, 2000). The process also may require religious or ritual slaughter (Halal) where in some cases stunning may be allowed or restricted depending on the customer's requirements.

2.4.4 Carcass characteristics

Carcass characteristics have been evaluated using different components from the slaughtered animal these characteristics include dressing percentage, carcass weight, ratios of lean, fat and bone and weights of non carcass components.

Dressing percentage

Dressing percentage (DP) is one of many factors affecting the value of a slaughtered animal. Dressing percentage (DP) for an individual animal has been defined as hot carcass weight divided by final live weight (Owens *et al.*, 1995). Owens and Gardcrner (2000) reported that under feedlot management and nutrition, DP had the greatest perceived economic importance because it relate liveweight to carcass weight and thereby, carcass value. However, Skunmun *et al.* (2002) argued that higher dressing percentage may not always yield higher returns. Therefore in assessing performance parameters DP should be considered in relation to other carcass quality for example the level of fatness. Dressing percentage is both a yield and value determining factor and therefore an important parameter in assessing performance of beef cattle (Malope *et al.*, 2007; Fadol and Babiker, 2010).

Slaughter and carcass characteristics have been reported by various authors in Africa (Table 8) and in Tanzania (Table 9). Like in slaughter characteristics (Table 8) there is a huge variation in the parameter measured (DP, carcarss weight and the proportion of lean, bone and fat.) in animals fed low to high plane of nutrition. The data demonstrated the different potential of each breed with respective to management, where extreme superior carcass performance could be attributed by animal frame size. Another carcass characteristic is the composition which is expressed in terms of physically dissected tissues in particular lean, bone and fat or chemically analysed constituents for nutrient concentration like amino acid and fatty acid profiles (Moran and Wood, 1986). The value of carcass depends on the edible meat yield (muscle and limited amount of fat) and of importance is how that meat is distributed in the carcass and other quality traits of meat (Johnson *et al*., 2005). On the other hand increase in carcass fatness has been reported to improve tenderness and provides insulation to muscle against cold shortening effects from rapid refrigeration (Wood *et al.*, 1999).

Table 8: Carcass characteristics of cattle in Africa

Breed	SW (kg)	CW (kg)	DP (%)	Percent carcass C (%) Lean	Fat	Bone	Author
Charolais	515	312	61	81	4	15	Strydom (2006)
Charolais X Nguni	379	224	59	78	5	17	Strydom (2006)
Ankole bulls	249	127	51	-	-	-	Asizua *et al.*(2009)
Ankle x Boran bulls	250	129	52	-	-	-	Asizua *et al.*(2009)
Ankole x Friesian bulls	255	130	51	-	-	-	Asizua *et al.*(2009)
Butana cattle steers	291	154	53	78	4	18	Osman (1985)
White Fulani bulls	418	251	60	-	-	-	Ngere (1985)

SW = Slaughter weight; CW = Carcass weight; DP = Dressing percentage; C= Composition

Table 9: Slaughter and carcass characteristics of indigenous cattle Tanzania

Breed	SW (kg)	CW (kg)	DP (%)	CL (cm)	Percent carcass C (%)			Non-carcass (kg)			Percent (%)		Author
					Lean	Fat	Bone	Rib	Pluck	Kidney	GC	EGC	
TSHZ	282	144	51	110	-	-	-	-	-	-	-	-	Mpiri (1994)
TSHZ (Tz No. 1)	294	156	53	-	77	1.7	21	-	-	-	-	-	Mpiri (1994)
TSHZ (Tz No. 2)	239	122	51	-	74	1.1	25	-	-	-	-	-	Mpiri (1994)
Boran	414	219	53	126	-	-	-	-	-	-	-	-	Macha *et al.* (1988)
Iringa Red Zebu	287	144	50	124	64	1.7	9	7	4.9	1.2	57	17	Nalaila, (2005)

Note: TSHZ = Tanzania Shorthorn Zebu; Tz=Tanzania; IRZ = Iringa Red Zebu; SW = Slaughter weight; CW = Carcass weight; DP = Dressing percentage; C= composition

Boran cattle have superior performance in most of the parameters reported in Tanzania and most parts of Africa compared to other indigenous animals. The possible reason for such superiority performance could be related to the genetic potential differences, that Boran breed is relatively a larger frame compared to some TSHZ which have small frame. Most of these characteristics reported are directly influenced by animal body frame size as was noted by other authors (Msanga *et al.*, 2001; Owens *et al.*, 1995). Carcass classification is extremely important when considering meat quality traits. Andersen *et al* (2005) reported that as meat quality traits are considered commercially, carcass classification for conformation, fatness and colour determines the market price, within each carcass weight range.

Likewise, Albertí *et al.* (2005) indicated that breeds with the best conformation tend to be more economically valuable and poor conformation is penalized. Thus economic profit for each carcass is dictated by the carcass classification, so it should be accurate and objective. According to MAFS (2003), the grading system in Tanzania is in two ways i.e. live animals involving live cattle grading and slaughtered animal (carcass grading). Live animal grading is normally done at large auction market at Pugu livestock market, Dar Salaam. However, there is limited information available on carcass characteristics in relation to carcass classification of indigenous Tanzania cattle breeds when concentrate diets are used and feedlot management is employed. Similarly, the practice of carcass classification is not common.

Fat occurs in the carcass as subcutaneous, intermuscular and intramuscular. Intramuscular fat consist of fat cells situated in the perimysium and the endomysium, surrounding the myofibrils and muscle fibre bundles (Wood *et al.*, 1999). The degree of marbling is the primary determinant of quality grade. According to Hale *et al.* (1998) marbling (intramuscular fat) defined as the intermingling or dispersion of fat within the lean, where graders evaluate the amount and distribution of marbling in the ***Longissimus dorsi*** (LD) muscle at the cut surface after the carcass has been ribbed between the 12th and 13th ribs. Intramuscular fat is known to develop late in the maturation of cattle and the content of fat increases with higher age (Pethick *et al.*, 2004). In most of the European countries consumers generally select against meat with such marbling (Ngapo and Dransfield, 2006; Webb and O'Neill, 2008) while in Australia marbling is an important parameter in carcass classification system.

Marbling is an important consideration in determining quality grade (Meat Standards Australia, 2008). Good nutrition has shown to improve body condition score of slaughtered cattle. Mpairwe *et al.* (2003) reported the improved body condition score of Ankole cattle from 5.3 to 7, Ng'anda cattle from 6 to 6.4 and crossbreds from 5.5 to 7.3 under high level of feeding management. The study further indicated that better fed animals dominated the carcass in the quality and choice for export grades in Uganda. Such slaughter and carcass attributes within the region may support the hypothesis that the indigenous cattle in Tanzania may respond equally well when fed high energy diets under good management like feedlot condition.

2.4.5 Handling of carcass after slaughter and ageing

Carcass handling after slaughter, has a significant influence on meat quality particularly, tenderness of the meat. Morgan *et al.* (2002) reported that very rapid chilling immediately after slaughter causes the muscle fibres to contract strongly except for those being stretched by the weight of the carcase (e.g. tenderloin). The shortening of muscle bundles resist shear forces and cause the meat to be 'tough'. The relaxed (stretched) muscles on the same chilled instantly carcass are elongated and 'opened out' and thus remain relatively tender. Recent study by Eskildsen *et al.* (2010) indicated that pelvic suspension is beneficial in tenderizing LD muscle from Ankole bulls and reduces the age-induced increase in toughness normally found in older animals. Also Purslow, (2002) indicated that improvements in quality of livestock carcasses and cuts accompanied by more appropriate handling could occur in the form of fewer bruises, improved tenderness, lower incidence of dark cutting beef, and lessened occurrence of pale, soft, exudates (PSE) and dark, firm, dry (DFD), where proper handling of meat animals can improve productivity, quality and profitability.

Various workers have been focusing on improving meat tenderness using various technologies. Among the technologies used include post mortem storage (ageing/maturing) of the carcass (Sentandreu *et al.*, 2002; Jayasooriya *et al.*, 2007), carcass hanging (Eskildsen *et al.*, 2010), mechanical/blade tenderization (Wheeler *et al.*, 1990a; Bowker *et al.*, 2007) and electrical stimulation (Wheeler *et al.*, 1990b). Ageing is among the technologies that has been recognized and employed by the meat industry for a long time (Taylor, 2003; Lawrie and Ledward, 2006). The term ageing refers to a natural process of tenderization when meat is stored or aged post-rigor. Warris (2004) reported that tenderization was attributed by two processes: changes in the connective tissue components of the meat or weakening of the myofibrils. Earlier Nishimura *et al.* (1998) suggested that tenderization was in two phases: there is rapid first phase caused by the changes in the myofibrillar component and a slower second phase caused by structural weakening of the intramuscular connective tissue. The authors however concluded, that the change in the myofibrillar component was more important and, very small changes were seen in the major connective tissue components such as collagen.

Koohmaraie, (1996) reported that different ageing times and conditions were a major cause of variability in beef when tested at various research centres in Europe. Further indicated that at slaughter all animals with the same pre-slaughter treatments had the same tenderness level, but the differences in tenderness were created in the first 24 h post- mortem. There is large variation in tenderness (shear force) after one day of post-mortem storage and that maximum toughness was further reported to occur at 9-24 h (Koohmaraie, 1996). After 24 h, an increase in tenderness is observed as a result of enzymatic degradation of muscle tissue. Temperature of storage can affect this enzymatic degradation, as well as other factors including pH, muscle fibre type, amount and degree of cross-linking of connective tissue, and animal species (Smulders *et al.*, 1992). The ageing process takes 1-2 days in chicken, 3-6 days in pork, and 10-20 days in beef (Smulders *et al.*, 1992). The technique of ageing meat at 0 – 2°C for 14 days was reported to be the common way of improving tenderness (Lewis *et al.*, 1991; Taylor, 2003).

The mechanism of tenderization has further been reported to be a result from the activities of proteolyitic enzymes present in the muscles. Their normal role is in the breakdown and recycling of the proteins which occurs continuously in all living tissues. The two important enzymes involved include the cathepsins and calpains, of which, at least in red meat species and poultry, the calpains are thought to be more important (Goll *et al.*, 2003). This process of ageing requires specific equipment and running costs are expensive, and may not be easily available in developing countries. The tendered meat produced therefore have higher price of which the consumer has to pay for it. It is of concern that in developing countries the costs of eating tendered meat may be limited due to the fact that local people of whom the majority are poor may not afford and this quality parameter may not be of necessity. Some plant substances have been reported to have tenderizing effect (Christensen *et al.*, 2009). The best known plant is papaya fruits, which contain a protein breaking down enzyme called 'papain', and the other is the Kiwi fruit which have similar proteolytic enzymes, though not as effective as papaya.

2.4.6 Carcass composition and the use of 6th rib joint compositin

The carcass composition is an aspect of the slaughter value of an animal. One of the factors which are important in beef cattle and meat yield is carcass composition which is expressed in terms of physically dissected tissues or chemically analysed constituents (Mushi *et al.*, 2007). The physical dissection consider the relative proportion of lean, fat and bone while the chemical composition evaluates the contents of protein, ether extract, water and ash (Oliván *et al.*, 2001). Estmation of carcass composition of large animals like cattle using whole carcass dissection is difficult. The use of different joints has been attempted where there was a high correlation between separable tissue analysis of the full 10th rib sample joint and of the full side (Mpiri, 1994). However, the use of 10th rib joint has been discredited because of its effect on carcass value. It has been found that full dissection of the 6th rib is more appropriate than dissection of the 10th rib as it can provide a good estimate of the carcass composition (Oliván *et al.*, 2001).

2.4.6.1 Physical composition

The main parameters of carcass quality are lean and fat proportions, lean: bone ratio and sealable meat yield (Johnson *et al.*, 2005). The difference in carcass composition is usually associated with the amount of fat deposition following the available plane of nutrition and the final slaughter weight of the animal, that means the amount of fat in a carcass may thus affect its nutritive value based on meat healthiness, flavour and juiciness (Platter *et al.*, 2003; Pratiwi *et al.*, 2004; Mushi *et al.*, 2007).

According to O'Mara *et al.* (2009), the content of bone, fat and muscle as percentage of cold carcass weight varies with fat cover and muscling of the carcass. Hot carcass weight can range from 44 – 55% of liveweight with very lean and poorly muscled cows having less hot carcass weight compared to fat and heavy muscled cows. Cold carcass weight (CCW) is approximately 99% of the hot carcass weight due to loss of water during chilling. Very lean carcasses will have greater moisture losses than fat carcasses. Bone can range from 17 – 32 % of the CCW and fat can range from 7 – 30% of the CCW. The greater the backfat on the cow the greater the percentage fat will be. Lean (muscle) content in the CCW can vary from 49 - 63%, but it is not the same in linear relationship as exists with fat and bone. Percentage muscle is lowest with fat cows and highest for cows that are heavily muscled, with an ideal body condition score. On overall, the value of carcass is largely determined by the edible meat yield i.e. muscle and limited amount of fat, and how that fat is distributed in the carcass and other quality traits of meat (Johnson *et al.*, 2005; Mushi *et al.*, 2007).

2.4.6.2 Chemical composition

Earlier studies have indicated that moisture and protein in meat decrease linearly with increase in supplementation where as carcass fat increased with increase in concentrate on offer (Berg and Butterfield, 1976; Marinova, 2001; Safari *et al.*, 2009). Recent study by Shija *et al.* (2009) reported on meat chemical composition for Boran and Tanzania Shorthorn zebu. The results showed that finishing steers on concentrate supplementation increases the proportions of fat in both Boran and TSHZ and decrease on the proportion of protein.

2.5 Meat Quality Attributes

Beef quality refers to the expected eating characteristics (tenderness, juiciness and flavour) of the cooked product (Tatum, 1996). The term 'meat quality' has been referred to as the inherent properties of meat decisive for the suitability of the meat for eating, processing and storage, including retail display (Andersen *et al.*, 2005). The main attributes of interest in meat quality include safety, nutritional value, flavour, texture, water-holding capacity, colour, fat content and composition, oxidative stability and uniformity. Likewise, the international markets also demands high standards of quality assurance regarding diversity and of aspects related to environmental, ethical and animal welfare problems in the production of meat (Warris, 2004). Some of the major components of quality beef attributes are summarized in Table 10.

Table 10: Summary of major components of meat quality in developed countries

Component	Description
Yield and gross composition	Quantity of saleable product, ratio of fat to lean, muscle size and shape
Appearance and technological characteristics	Fat, texture (tenderness) and colour, amount of marbling in lean (intramuscular fat), colour and water holding capacity of lean, chemical composition of lean
Taste	Juiciness, flavour
Wholesomeness	Nutritionally quality, chemical safety, microbiological safety
Ethical quality	Acceptable husbandry of animals and slaughtering

Source: Warris, (2004)

Among the quality beef attributes given in Table 12, tenderness is considered to be the most important eating quality attributes, which influence the consumers overall judgement and perception of meat, particularly beef (Gerelt *et al.*, 2000; Glitsch, 2000; Burke and Monahan, 2003). Lepetit and Culioli (1992) defined tenderness of meat as "the ease, perceived by the consumer, with which meat structure is disorganised during mastication" and as such is considered as a sensory property. Although tenderness cannot be strictly defined in physical terms, it involves the aptitude of meat to be deformed and broken down during mastication and therefore depends directly on the mechanical properties of the meat (Culioli, 1995). Fukumoto *et al.* (1995) reported that meat from the hindquarters is made up of much larger muscle groups, with less cartilage and connective tissue and is therefore tenderer. Meat with the fat deposited within the steak to create a 'marbled' appearance has always been regarded as tenderer than steaks where the fat is in a layer around the outside. But there is a view (Belk *et al.*, 2001) that both stresses before slaughter in particular, and lack of aging of the meat has more to do with toughness than most other factors, including marbling.

Due to the importance of tenderness as an attribute of meat quality the parameter has been studied extensively. Scientists measure the force needed to shear muscles. The Warner-Bratzler shear test is a frequently used instrumental device to determine meat tenderness (Lepetit and Culioli, 1992) where high values (> 50 N) are recorded when the meat is tough. Its units of measurement are kilograms of force needed to shear a 1 cubic centimetre muscle sample. Christensen *et al.* (2007) reported that by performing this test on cooked meat samples force deformation curves are created from which the structural changes occurring in meat after a certain treatment are interpreted and thereby enable an in-depth understanding of the cause of change in tenderness. Interpretation of the structural changes giving rise to change in toughness can be evaluated by determining the initial yield and final yield on the force-displacement curves originating from Warner-Bratzler shear test (Christensen *et al.*, 2004).

The other method used to evaluate meat tenderness is a straight sensory panel test, where trained panellists eat the meat and record their perception of its tenderness. However, the major limitation of this method is that it requires well trained people and may be expensive in using them. Shackelford *et al.* (1997) classified carcass as "tender" "intermediate" or "tough" when its *Longissimus dorsi* muscle Warner-Bratzler shear force (WBSF) value at 1 or 2 days post-mortem was < 59 N, 59 to 88 N, or > 88 N respectively. It is obvious that use of the instrument WBSF will give values that will have similar degree of tenderness as the ranking made by trained sensory panellists.

Other meat quality attributes reported by Mushi *et al.* (2007) include meat ultimate pH, colour, water holding capacity and fatty acids content and composition. The ultimate pH is equally important as it increases from 5.5 to 6.0 as the tenderness of cooked meat decreases, and above pH 6.0 the effect is reversed (Braggins, 1996). In addition, meat with low pH may be of poor quality since enzymes involved in post-mortem tenderisation are inhibited by acidification. Low ultimate pH is associated with increased drip loss resulting in meat with poor overall acceptability (Maltin *et al.*, 2003). According to O'sullivan *et al.* (2004), meat colour may influence consumer decision to purchase meat, where meat from grazing pasture is relatively darker as a result of exercise. The composition of fatty acids in meat has significant influence on quality, as it is related to differences in organoleptic attributes, especially flavour and nutritional value (Olfaz *et al.*, 2005).

2.5.1 Water holding capacity attributes due to drip loss, cooking loss and thawing loss

Water holding capacity (WHC) is one of the most important attributes of meat quality from the consumer and processor point of view. Meat with a better WHC means less aging and thawing losses (Waritthitham *et al.*, 2010). The water holding capacity attributes include drip, cooking and thawing losses.

Drip loss is the loss of fluid from meat and water evaporation from the shrinkage of muscle proteins (actin and myosin) in the form of drip (Yu *et al.*, 2005). Drip loss in fresh beef cuts is an important challenge to maintaining an attractive retail display of meat. Normally, fresh post-rigor meat exudes fluid, or drip, from cut surfaces (Lawrie and Ledward, 2006). If cell membrane integrity could be stabilized post-mortem, sarcoplasm should be retained in muscle cells and thereby result in less drip loss and more weight retention during storage and display. Oxidative processes may contribute to the loss of membrane integrity. Drip loss is of high importance due to financial implications and beef with high drip loss has an unattractive appearance. Purslow (2002) reported that in normal meat the drip loss usually is between 1-5% and above that is considered as high drip loss. Jama *et al.* (2009) reported that high drip loss decreases meat tenderness and juiciness. Proteins, peptides, amino acids, lactic acid, purines, vitamins of the B complex and various salts are among the many constituents of drip loss (Purslow, 2002).

Various workers have reported on drip loss from beef cattle. A study by Mitsumoto *et al.* (1995) working on crossbred of beef steer and Holsten showed a drip loss of 7.0 and 7.5 % respectively. In addition they showed that drip loss increased with ageing from 2, 6, 10 and 14 days which was 3.2, 5.4, 8.5 and 11 % respectively. Jama *et al.* (2007)

observed no breed difference (P>0.05) on drip loss when they compared Nguni (0.97; 0.84 %), Bonsmara (1.05; 1.14 %) and Angus (0.71; 0.84 %) beef cattle at 2 and 21 days ageing respectively. However, breed differences in drip loss at the same ageing time have been reported among the indigenous (Sanga) cattle genotypes (Frylinck *et al.*, 2006). The values were Bonsmara (2.96%), Drakensberger (2.66 %), Nguni (2.44 %), Tuli (2.26 %), and Brahman which is zebu type (1.99 %). Brugiapaglia *et al.* (2008) found that Friesian had higher drip losses in comparison with crossbred (3.62% vs. 3.08 %; P<0.05) and higher amount of maize grain in the diet reduced drip looses (2.61 vs. 3.09 %; P<0.05). In addition, ageing was found to induce an increase in drip loss with significant differences for d 5 (2.25%) in comparison with d 8 (3.12%) and d 10 (3.4%) and between d 7 (2.65%) and d 10.

Another meat quality attribute is the cooking loss which refers to the reduction in weight of beef during the cooking process (Drummond and Sun, 2005). The major components of cooking losses are thawing, dripping and evaporation. The different components of cooking loss may vary depending on the ageing period. Furthermore the cooking components may also be related. Protein denaturation occurs when meat is cooked, but also when its pH is greatly changed (e.g. acid or alkaline marination), or when fast rates of pH fall post-mortem occur while the muscle is still at high temperatures (leading to the development of pale, soft exudates (PSE). Pale, soft exudates occurs when pH drops rapidly while the muscle is still at high temperature (Purslow, 2002). Holding connective tissue at high temperature for extended periods results in gradual solubilization of collagen as cross-links are broken down. Solubilisation of collagen on long-term cooking of meat is associated with a reduction in meat toughness. This solubilisation effects works to reduce the toughness of the muscle even if it has been cold-shortened or proteolytically aged (Davey *et al.*, 1976).

A study by Mitsumoto *et al.* (1995) working on crossbred of beef steer and Holsten showed no breed difference (P>0.05) on cooking loss of 27.6 and 27.8 %. In addition they showed that cooking loss decreased with ageing from 2, 6, 10 and 14 days as follows: 30, 29, 27 and 24 % respectively. Jama *et al* (2007) observed breed differences (P<0.05) in cooking loss between Nguni (25.1; 23.2 %), Bonsmara (23.5; 23.4 %) and Angus (24.9; 23.9 %) at 2 and 21 days ageing respectively. In addition Jeremiah and Gibson (2003) reported cooking losses of 22.5 %. In contrary, Razminovicz *et al.* (2006) reported higher values (30 %) from steers fed on pastures. Ageing induced an increase (P<0.05) in cooking losses at day 10 compared to 5 and 7 days ageing (18.20 vs. 16.96 % and 16.68%).

Other workers have also reported cooking losses from different breeds and diets. A study by Fiems *et al.*, (2003) reported cooking loss from Belgian blue bulls and cows (25.1 and 23.6 %). Also Brugiapaglia *et al.* (2008) observed no differences in cooking losses between breeds, Friesian (17.5%) and Friesian crosses (17.05 %), and between diets, when less maize grain (17.26 %) and higher amount of maize grain in the diet (17.34 %) was added to a basal diet that was maize silage. Various reasons have been reported to cause such huge variations in drip and cooking losses when meat from different breeds and diets is tested. Possible reason caused by breed difference is due to genetical potential of different breeds in marbling and other fat deposition giving different capacity in holding water resulting in decreasing cooking and drip losses for breeds with high potential for depositing fat during fattening (Jama *et al.*, 2007). Similar reasons could explain the variation obtained in different diets where diets that favour fat deposition with increasing ADG displayed the same trend (Immonen *et al.*, 2000 and Andersen *et al.*, 2005a). Reason for increasing drip and cooking losses with increasing ageing time could be due to breakdown of myofibrillar which reduce the water holding capacity and increase cooking and drip losses.

Thawing loss refers to the loss of fluid in meat resulting from the formation of exudates following the removal of meat sample from the freezer to the refrigerator. Studies have reported that the advantages of temperatures below the freezing point in prolonging the useful storage life of meat, and in discouraging microbial and chemical changes tend to be offset by the exudation of fluid ('drip') on thawing. A study by Jama *et al.* (2007) showed that no breed difference (P>0.05) on thawing loss between Nguni (3.26; 2.59 %), Bonsmara (3.35; 2.23 %) and Angus (3.60; 2.8 %) beef cattle at 2 and 21 days ageing respectively. In conclusion, it has been revealed that WHC and subsequent loss are complex attributes of meat which are influenced by the factors in the whole production chain as reviewed by Den Hertog-Meischke *et al.* (1998).

2.5.2 Post-mortem temperature decline

The variation in temperature effects that can occur in a muscle due to metabolic differences is presented below Figure 2. The low ultimate temperature is due to the meat being chilled at different time intervals.

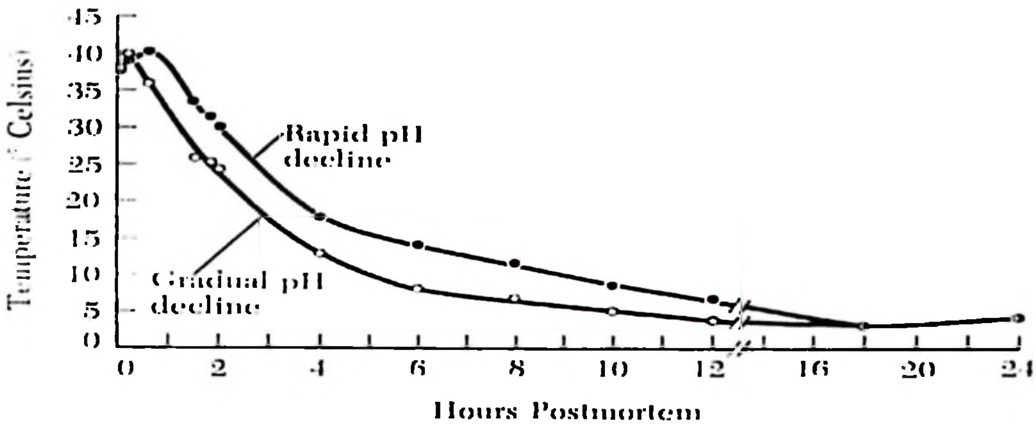


Figure 2: Postmortem temperature decline curves (Forrest *et al.*, 1975)

Similar trends were reported by other workers for different animal species. A study by Sinclair *et al.* (2001) observed no breed difference on temperature decline of the LD muscle within 1 h post-mortem, from three beef breeds Aberdeen Angus (34.8 °C); Charolais (35.6 °C); Holstein (33.5 °C) but the difference was observed after 10 h post - mortem for Aberdeen Angus (16.3 °C); Charolais (18.0 °C) and Holstein (14.8 °C). Diaz *et al.* (2002) reported that the rate of muscle temperature decline during the immediate post-mortem period has significant implications on meat quality attributes in sheep. Similar views were reported by Abdullah and Musallam (2007) also in sheep. Reasons for such trends are several. It is known that just after slaughter, immediately the circulation fails with exsanguinations, heat production by the anaerobic metabolism in the muscle causes a rise in post-mortem temperature. At death, animals have a body temperature of between 37 and 39°C (Warris, 2004).

2.5.3 Changes in pH post-mortem

Generally, pH has little economic importance, but it is often used as a predictor of other measures of quality including colour, moisture, WHC and sensorial properties (Melody *et al.*, 2004). The pH has implications in the quality of meat in terms of colour and keeping quality (Van Laack *et al*., 2001; Melody *et al*., 2004) and the rate of pH fall depends on the muscle temperature and glycogen reserve. The precise relationship between tenderness and pH is complex and not fully understood. Studies have shown that exercises immediately pre-slaughter have appreciably negative effect on glycogen reserves in muscles. The conversion of glycogen to lactic acid will continue until a pH is reached when the enzymes breakdown become inactivated. In a typical mammalian muscle this pH is about 5.4 - 5.5 (Warris, 2004). There is some evidence that residual glycogen increases the WHC and tenderness of the muscle when cooked (Immonen *et al*., 2000) and that there will be no residual glycogen if the pH fails to fall to 5.4-5.5 during post-mortem glycolysis (Rosenvold *et al*., 2002). Figure 3 shows the range of variation in pH decline observed in pigs. The normal pattern is for pH to drop to about 5.6-5.7 within 6-8 h post-mortem, and to reach an ultimate pH (pHu) of around 5.5. However, this varies a little from muscle to muscle.

It has been reported that after slaughter pH decrease and the final values have been attained 24 h post-mortem (Marsh *et al*., 1988). A normal pH decrease from pH 7.2 in the living muscle to a pHu of 5.5 can be observed in well-fed unstressed pigs, depending on the muscle glycogen level (Lawrie and Ledward, 2006).). Bruas-Reignier and Brun-Bellet (1996) reported the mean pH value of the carcass as 5.65 which is within the normal range according to the literature (5.4 – 5.7).

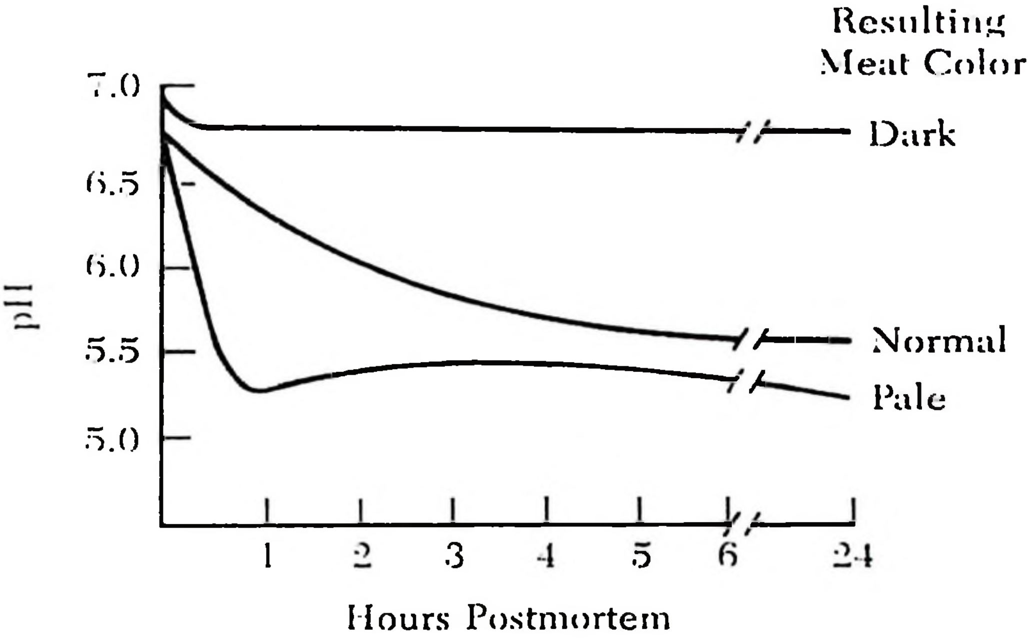


Figure 3: Postmortem pH decline curves (Forrest *et al.*, 1975)

A study by Van Laack *et al.* (2001) revealed that the rates of pH decrease and pHu have major consequences on the eating quality. Meat with high pHu (often > pH 6.5), is described as dark cutting or dark, firm and dry, occurs when animals have lower than normal muscle glycogen levels at slaughter and as a result lactate production is low (40μm – lactate/g muscle) at pHu 6.2 compared with 100 μm lactate/g muscle in normal meat. However, the tenderness of meat with high pHu has not been fully agreed on (Maltin *et al.*, 2003). Some studies have reported that the meat may be more tender than normal because the reduction in availability of glycolytic substrate which causes more rapid ATP depletion and early rigor. The latter reducing susceptibility to cold shortening and allows prolonged activity of proteases (Wanatabe *et al.*, 1996). In contrast, meat with low ultimate pH is likely to be of poorer eating quality. This is because the enzymes involved in post-mortem tenderization are inhibited by the acidification, and low pHu is also associated with increased drip loss resulting in meat with lower overall acceptability.

Studies by Sinclair *et al.* (2001) observed no difference on pH decline of the LD muscle within 1 h and at 48 h post-mortem, from three beef breeds Aberdeen Angus (6.28 and 5.71); Charolais (6.44 and 5.71); Holstein (6.38 and 5.73). Also no breed differences in pH decline on LD muscle were observed at 24 h pm among the indigenous (Sanga) cattle genotypes (Frylinck *et al.*, 2006). The pH values observed were Bonsmara (5.58), Drakensberger (5.64), Nguni (5.76), Tuli (5.66), and Brahman a zebu type (5.67). Smilarly, Monsóon *et al.* (2004) observed no difference on pH at 24 h post-mortem between Holstein (5.52), Old Brown Swiss (5.51), Limousin (5.55) and Blonde d'Aquitaine (5.52). Diets did not show differences (P>0.05) in 1 and 48 h post-mortem, where the pH on LD muscle from different energy levels were (a) moderate was 750 KJ ME per day per kg $M^{0.75}$ (6.22 and 5.67), (b) high was 1050 KJ ME per day per kg $M^{0.75}$ both for 20 weeks (6.42 and 5.82) (c) moderate for the first 10 weeks followed by high for the remaining 10 weeks (6.44 and 5.68). Changes in pH have also been reported for other species that produce red meat. A study by Van Laack and Kauffman (1999) reported a strong correlation between the pHu of the muscle and its ability to produce lactate. Mushi *et al.* (2009) observed a faster decline in goats' carcass pH values in the first 6 h post-mortem while the decline more-less leveled off afterwards. The authors further noted that at pHu for carcasses obtained from goats fed *ad libitum* concentrate was within the acceptable range, 5.6 – 5.8 (Pratiwi *et al.*, 2007). The absence of breed and diet differentces in pH and pHu in the above studies could be due to the uniformity cooling that was within the acceptable window not to affect pH changes.

2.6 Profitability of Finishing Cattle

The overall objective of feedlot finishing is to get a high ADG and thereby increasing body condition score, dressing percentage and meat quality. The cost per shillings of production and the price received for the product are major factors that determine profitability of beef production enterprise. Earlier findings by Andersen *et al.* (2005)

indicated that animals finished from different production systems and using different diets differ in quantity and quality. The obtained product would bring different prices in the market such as prices for choice meat, good quality and standard grade meat. From other workers (Malope *et al.*, 2007) it has been argued that, the income for the various beef production treatments is determined not only by the total shillings of trimmed retail beef produced, but also by the amount of the quality grade of beef produced and the price differential among them. Furthermore, the price of the feed used in the fattening ration does, to a large degree, determine the costs of the finished product. Therefore, the decision of choosing the appropriate feeding alternatives can be evaluated somewhat in advance depending upon the objectives for quality grades to be produced and the expected price at the market place.

Feed accounts for 70–80% of the variable costs under feedlot condition (Henning, 1999). The high feed costs in feedlot systems, particularly protein supplements are indications of the need to improve profitability through alternative sources of quality feed raw materials which can supply the nutrient needs of beef cattle more cost-effectively. This is imperative especially for small-scale farmers for whom low feed cost is critical in improving profit margins. High growth rate during feedlot finishing requires a high energy intake, which is normally obtained from concentrate diets (Weisbjerg *et al.*, 2007). Skunmun *et al.* (2002) pointed that marginal costs consideration are very important in beef production because of rapidly changing feed costs and beef prices and because they differ materially from the average costs analysis. Similar argument was given by Norris *et al.* (2002) that, ultimately, what the farmer look for are the financial returns of the beef cattle enterprise, where the economic and financial viability of feedlot fattening is largely determined by the beef-feed price ratio. It is also reported that feed is the major single cost item of the variable costs in a feedlot enterprise. These production traits are in turn influenced by the breed group (its potential for growth and mature size) and will vary depending on the specific production environment.

2.7 Inference from the Literature Review

From the literature reviewed it can be concluded that the quantity and quality of beef could be improved through crossbreeding and improved nutrition as a long term goals. whereas in the short term goal the available indigenous breeds could be used with proper manipulation in nutrition under feedlot condition. As a pre-requisite, however, pre-slaughter handling of animals and post slaughter handling of carcass need to be observed for improved quantity and quality of beef that can be acceptable by both domestic and export markets.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Introduction

Two experiments were carried out with the main aim of improving the quantity and quality of meat produced from the indigenous cattle breeds in Tanzania. The experiments were carried out at Kongwa Ranch belonging to the National Ranching Company (NARCO). The first experiment was conducted during wet season (December 2007 to March 2008), whereas the second one was conducted during the dry season (September to December 2008). In each experiment, growth performance and feed intake were measured. Slaughtering, and carcass assessment including carcass measurements, temperature and pH readings and ageing of meat were done at Dodoma abattoir, Dodoma. Warner-Bratzler Shear force (WBSF) determination was conducted at the Department of Animal Science and Production of the Sokoine University of Agriculture, Morogoro.

3.2 Description of the Study Location

The study was conducted at Kongwa Ranch located at S 6° 03.810' and E 36° 27.296' in Dodoma region, about 82 km from Dodoma capital city on Dodoma Morogoro highway and 15 km from Kongwa District headquarters (Figure 4). Kongwa ranch is about 1067 m above sea level. Topographically it is undulating with sandy and loamy sand soils. The ranch receives rainfall of about 254 – 660 mm per annum. Temperatures range between 23 – 32 °C depending on the months in a year. The area is a typical representative of most semi-arid areas where majority of livestock are kept.

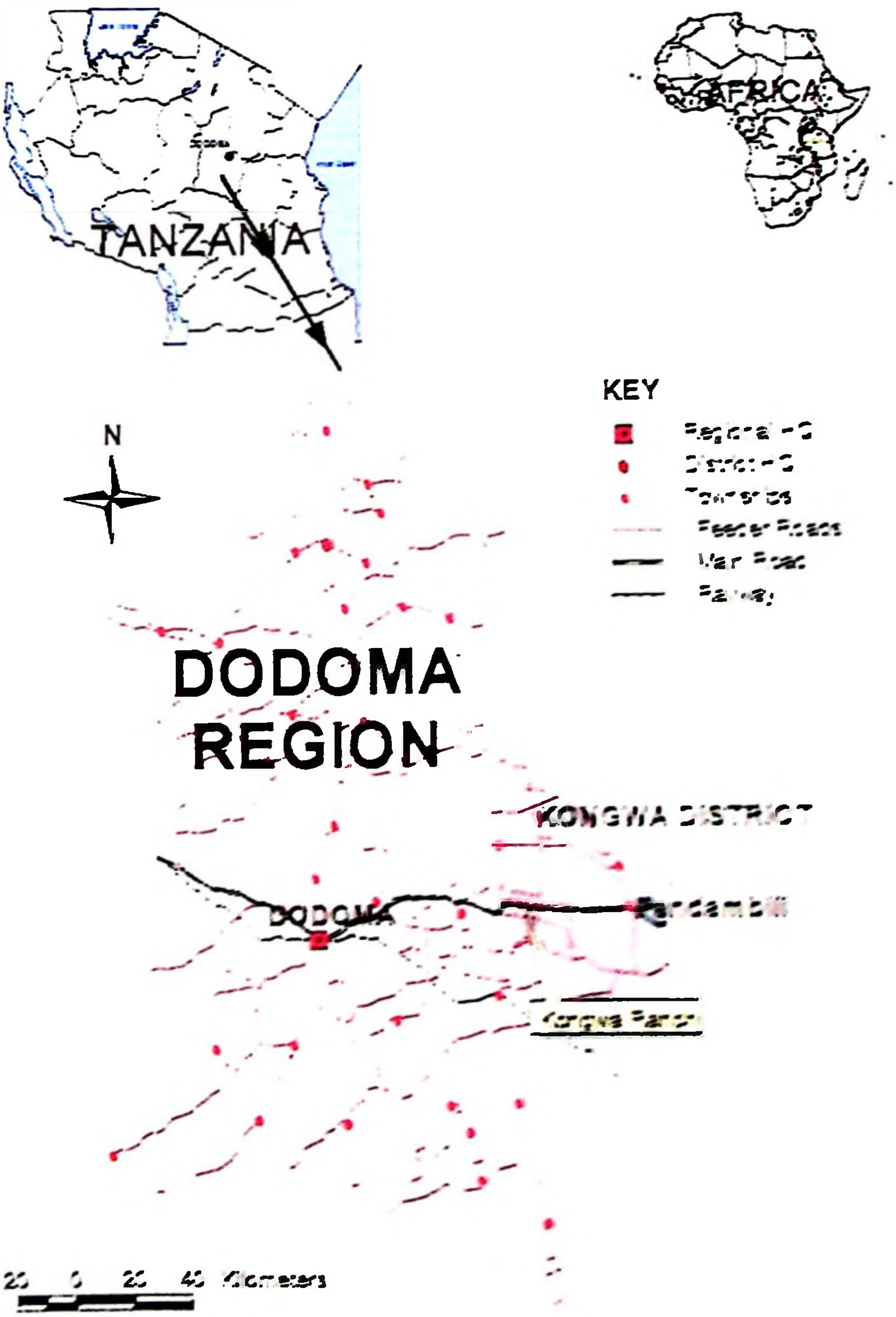


Figure 4: Map showing location of experimental feedlot site at Kongwa ranch.

Kongwa District, Dodoma

Kongwa ranch is the biggest ranch in the country among the eight ranches under National Ranching Company (NARCO) (MLDF, 2008). Kongwa ranch was selected for the study because of its historical background of producing Kongwa beef that is preferred by many local consumers. The ranch is also close to the Dodoma Modern Abattoir which has facilities for cooling the carcasses. Further more it is easier to let carcass for sale from Dodoma to Dar es Salaam city where there is higher demand for quality beef.

3.3 Experiment I: Finishing Cattle During Wet Season

The main aim of this experiment was to evaluate the effects of five different dietary treatments on performance, carcass and meat characteristics of two breeds of cattle (Tanzania shorthorn zebu (TSHZ) and Boran). The study also examined the effect of meat ageing on meat tenderness.

3.3.1 Experimental design and treatments

A total of one hundred and twenty (120) steers composed of sixty (60) Boran, and sixty (60) Tanzania Shorthorn Zebu (TSHZ) were randomly allocated to five dietary treatments in a 2 x 5 factorial experiment in a completely randomized design. The main factors studied were breed effects (Boran and TSHZ) and dietary effects (five treatments). The diets comprised of grazing with no concentrate as a control (Graz+C00); grazing plus 50 % *ad libitum* concentrate intake (Graz+C50); and *ad libitum* hay plus 60% of the *ad libitum* concentrate intake (Hay+C60); *ad libitum* hay plus 80% of the *ad libitum* concentrate intake (Hay+C80) and *ad libitum* hay plus *ad libitum* concentrate intake (Hay+C100). The 50, 60, and 80 % *ad libitum* concentrate intake was calculated basing on the fresh intake of the previous day 100% *ad libitum* concentrate intake. A*d* *libitum* feeding was taken to allow 10 – 15 % refusal. Each pen was used as an experimental unit for feed intake and feed conversion efficiency where as an individual animal was considered as an experimental unit on weight changes, carcass and meat quality analysis.

3.3.2 Source of experimental animals and management

Steers of TSHZ Gogo strain were purchased from Kizota, Kigwe, Mpunguzi and Bahi auction Markets, in Dodoma region. Boran steers were purchased from the ranch. The age of steers ranged between 1 and 2 years for Boran and 1.5 and 2.5 years for TSHZ. The age of the TSHZ were estimated based on their dentition while that of Boran steers were obtained from ranch records. Animals were weighed on arrival and prophylactic treatment such as vaccination against *Contagious Bovine Pleuropneumonia* (CBPP) was administered to the animals on arrival. The animals were dewormed using albendazole. Eleven TSHZ steers were re-castrated using Burrdizo.

Grazing animals were treated against parasites after every ten days through dipping them in a common dip containing Bayticol EC 6% with Dilution of 1000 ml per 1500 litres of water. Animals kept under feedlot pens were treated against parasites after every ten days by hand spraying using Parannex 100 EC 6%. Dilution was 10 ml of PARANEX per 20 litres of water. Deworming was done on arrival and in the mid of the respective experiment, where *Tramazole:albendazole* 10% W/V drench was used. Other diseases were treated as they occurred using *Oxytetracycline* 10% (250 mls to 100 mg/ml). Animals were monitored daily for their behaviour and health status.

Steers were ear tagged for experimental identification. A preliminary period of 7 days was followed whereby all steers were mixed and received common feeding and other management. This period was meant to remove any managemental differences from their source of origin. The steers grazed for 7 hours and had access to hay near the feedlot structure for about 1 hour. In the evening steers were enclosed in wire fenced kraal near the experimental area for overnight. During the last three days of preliminary period the animals were weighed for three consecutive days to obtain their average initial liveweight which was used to allocate them to dietary treatments and grouping them into pens. Animals were weighed prior the morning feeding.

A feedlot structure constructed at Kongwa Ranch with a total of 24 pens with dimension of 4 X 5 m was used for the study. The structure was partially roofed with iron sheets where the feeding and watering troughs were placed and a little bit of shed to protect the animals during the mid day sun (palm thatched) at the mid of the pen to the rear end (Plate 1). Steers on Graz+C00 (grazing alone) were kept outside in a wire fenced kraal at night. Steers on Graz+C50 were confined during the night in their respective pens where they received concentrate. All steers on Hay+C60, Hay+C80 and Hay+C100 were confined in separate pens throughout the experimental period.

After the allocation of the animals in their respective treatments and pens, animals had 19 days for familiarization to the feeds, pens and experimental protocol. During familiarization, animals in Graz+C00 were grazing; animals in Graz+C50 were grazing and later in the evening were taken to respective pens and supplemented with concentrate. All animals in Hay+C60, Hay+C80 and Hay+C100 were given hay *ad libitum* and proportional concentrate supplementation were provided to animals in

Hay+C60 and Hay+C80 depending on the amount provided to animals in Hay+C100 in that day until *ad libitum* concentrate intake was reached.

Plate 1: Feedlot structure used for the feeding experiment at NARCO, Kongwa

3.3.3 Feeds, feeding and management

The hay used for feedlot in experiment number one was purchased from NLRI, Mpwapwa. Energy-rich concentrate diet was made from several ingredients. Maize meal was made from maize purchased from Kibaigwa grain market at Kongwa District, Dodoma region. Cotton seed cake was bought from Shinyanga cotton ginneries and molasses from Mtibwa Sugar Estate in Morogoro. Salt was purchased from Singida, mineral mix from Tanga and urea from local agro vet shops in Dodoma. Chemical composition and digestibility values for the ingredients used in the formulation of the concentrate diet were obtained from feedstuff tables and literature (Strudsholm *et al.*, 1999, Doto *et al.*, 2004). The concentrate was formulated to contain (g/kg) maize meal (380), cotton seed cake (130), molasses (470), mineral mix (10), salt (5) and urea (5). The calculated composition was 125 g CP and 12 MJ ME per kg DM, targeting an average daily gain of 1kg per day. The feed stuff that are protein based were computed in diet formulation using the popular Pearson square method as applied by Wagner and Stanton (2010) to determine the proper dietary proportion of feed stuff bearing about the protein requirement of the fattening steers. After preparing the ingredients, they were weighed and mixed in appropriate proportions to give the desired protein level. Grazing animals had access to water three times a day, in the morning, noon and afternoon when they were taken back to the kraal for night. The steers in feedlot had access to water throughout. The animals were given fresh water.

Fresh feed offered and feed refusals for animals in each pen were measured on daily basis. The differences were taken as the amount of feed taken in by four animals in each group. Feed intake in terms of dry matter was computed and was taken per pen and the value obtained was divided by the number of animals in the pen to obtain an average intake per animal. Animals were weighed in the 30th day and thereafter every two weeks until the end of the fattening trial. Animals were weighed three consecutive days prior to the date of slaughter and the average weight was taken as the final body weight of animals at termination of the experiment. Plate 2 shows the animals finished on feedlot.

Plate 2: Cattle finished under feedlot condition

3.3.4 Slaughtering of experimental animals and measurements

3.3.4.1 Slaughtering procedure

At the end of the feeding trial, all the experimental animals were taken for slaughter at Dodoma Abattoir for different days because of the space limitation in the chilling rooms for storing the carcasses. Twenty (20) animals were slaughtered on the 97th day, 40 on the 98th day, and 20 animals each day on on the 100th, 102nd and 104th day of the trial. The schedule followed for slaughtering animals, carcass measurements, sampling of Longissimus dorsi (LD) muscle and dissection of 6th rib joint is presented in Appendix 1. Animals that were transported each day for slaughter were picked from each treatment and breed randomly. The animals were transported on a track while standing perpendicular to the direction of travel. On arrival at the abattoir, the animals were inspected and all were accepted and kept in lairage in isolation from other animals. From the time of transporting the animals from feedlot to abattoir neither feed nor water was given. The animals were fasted for 13 - 17 hours prior to slaughter.

The animals were stunned using electrical stunner and immediately suspended by achilles tendon. The animals were slaughtered by severing the neck using a sharp knife. This was done by authorized Muslim personnel for the meat to be Halal. Thereafter, the suspended body was bled and skinned. The head was removed at the atlas joint, the forefeet was severed at the knee joint between the carpal and metacarpal bones and the hind feet was severed at the hock joint between the tarsal and metatarsals. The animal was deskinned, eviscerated and the tail cut off close to the junction of the sacral and caudal vertebrae. Plate 3 shows the skinning and splitting of the carcass.

Plate 3: Skinning and splitting of carcass at slaughterhouse in Dodoma

3.3.4.2 Non carcass measurements

Non carcass measurements included weighing of the internal organs (kidney and fat) and the fat surrounding the kidneys and the mesenteric fat (fat surrounding the gastro-intestinal tract -GIT) using a portable digital weighing balance. The weights of full gut and empty gut were weighed using a sorter balance.

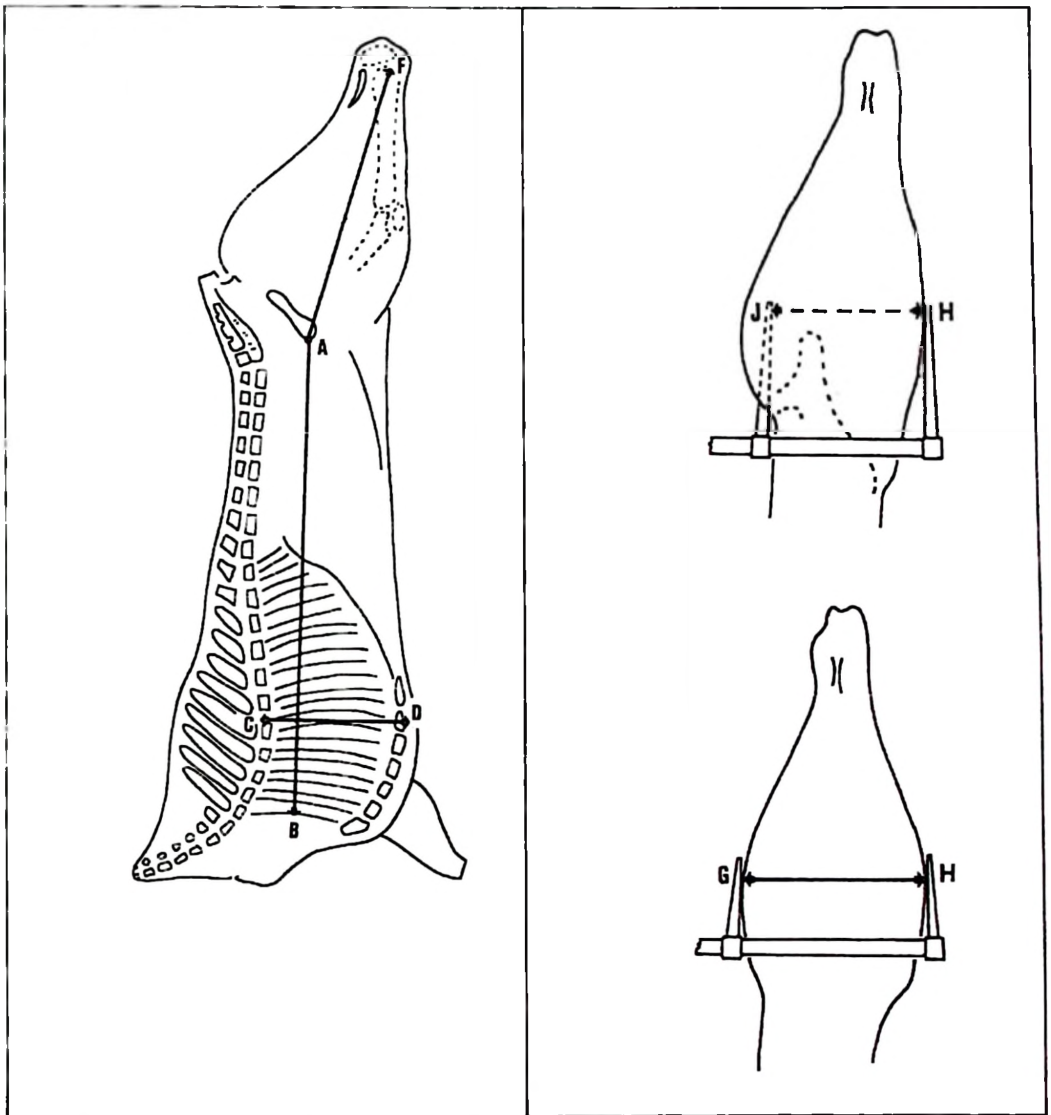
3.3.4.3 Carcass weight

The carcass was separated into left and right carcass (Plate 3) by cutting using a meat saw. Both left and right hot carcass weight (HCW) was taken using automatic electrical balance available at the abattoir. The total HCW was the sum of the left and right hot carcass weights. The split half carcasses were kept at room temperature for 10 hours and then transferred to a cold room set at 0 – 4 °C (Plate 4).

Plate 4: Dressed carcasses placed in storage room

3.3.4.4 Linear carcass measurements

Linear carcass measurements were taken as follows: carcass length from a cranial side of ischio-pubis symphisis (A) to the middle of the cranial side of the 1st rib (B); internal depth of the chest was measured from down side of medullar channel at the 5th -6th thoracic vertebra level (C) to the intersection down the side of external bone (D), with a line through the middle of the internal face of tarso-metatarso joint (F) and parallel to caudal side of 5th rib. Measuring tape was used to measure carcass length, internal depth of chest and limb length, whereas vernier caliper was used for measuring the limb width. The illustration for the carcass measurement is presented in Plate 5.



Keynote: A – B = Carcass length; C – D = Depth of Chest; A – F = Length of leg; G – H = Max width of leg; J – H Minimum width of leg

Plate 5: Illustration for the carcass measurement

3.3.4.5 Carcass grading

Carcasses were classified using a EUROP classification system (Appendix 2) for cattle (Borggard *et al.*, 1996). Carcasses were classified for conformation (scale from E = excellent to P = poor) into five classes divided into three sub classes: -, 0, or + to form 15 grades. The carcasses were also scored for fatness on a scale of 1 – 5 (1 = none or low fat cover to 5 = entire carcass covered with fat). High value for fat class indicated a carcass with a high degree of external fat (subcutaneous). High value for conformation class indicates a carcass with well to excellent rounded muscles.

3.3.5 Derived measurement

The following parameters were derived:

Average daily gain (ADG) = Final body weight - Initial body weight)/ number of days

Feed conversion ratio (FCR) = Feed consumed (kg) / kg of liveweight gain

Dressing percentage (DP) = (Hot carcass weight/Final liveweight) * 100

Weight of Gut content (kg) = Weight of full gut (kg) – weight of empty gut (kg)

Empty body weight (EBW) (kg) = Final liveweight (kg) – Weight of gut content (kg)

Percentage gut content of EBW (%) = (Weight of full gut /EBW)* 100

3.3.6 Measurements of meat quality parameters

A total of 64 carcasses (left side), 8 animals per dietary treatments Graz+C00, Graz+C50, Hay+C60 and Hay+C100 were sampled for meat quality measurements. Meat quality parameters assessed were carcass temperature, pH, carcass composition, and LD area.

3.3.6.1 Carcass temperature

Measurement of carcass temperature was taken at the 10th rib of the right side of the carcass in the *Longissimus dorsi* (LD) muscle. The temperature was measured by insertion of Digital meat thermometer (FUNKUTION Digital stegetermometer) to the muscle. The readings were performed at 45 minutes, 6, 24 and 48 h post-mortem (pm). Carcasses were kept at room temperature for 10 hours and then were taken to storage room. The temperature readings at 45 minutes and 6 h pm were performed at room temperature, while the readings at 24 and 48 h pm were performed while the carcasses were in chiller room. Before and after every reading the instrument was thoroughly cleaned with distilled water and wiped with cotton wool.

3.3.6.2 Carcass pH reading

Measurement for carcass pH was taken at the same area where temperature was measured. The rate of the pH fall in the LD was measured by inserting a penetrating electrode (Mettler Toledo) on the muscle at 45 minutes, 6, 24 and 48 h pm using a portable pH-meter (Knick-portamess 911, Germany). Using a scalpel blade, fat was cut through and the probe was inserted into the muscle at a slight downward angle and twisted gently back and fourth until when the pH was stable and the readings were then taken. The pH meter was calibrated at room temperature of 28°C in buffer solution for pH 7 and pH 4. The pH meter was again calibrated at 4°C of buffer solution for measuring pH of cold carcass at 24 and 48 h pm (the recorded pH at 48 hrs was the ultimate pH). The calibrations of temperature were as the internal temperature of the LD described by Rosenvold *et al.* (2002).

3.3.6.3 Carcass composition

The 6th rib sample joint of the left side of the carcass was obtained according to Robelin and Geay (1984) method and used to predict the whole carcass composition. The joint was weighed (kg) and then dissected into fat, lean and bone tissues. Fat was made up of intramuscular and subcutaneous tissues which included cartilage tissues. The weight of the components was then expressed as percentage of the joint weight to obtain the relative distribution of the tissue. The use of 6th rib joint have shown to give a good estimate of the carcass composition (Oliván *et al.*, 2001).

3.3.6.4 Measurement of Longissimus dorsi (LD) area

The *Longissimus dorsi* (LD) was traced over the 5th rib from the same left side of the carcass that remained during removal of the 6th rib. The area of LD was measured by placing an A4 standard transparency on top of the LD. The area was then drawn by tracing with a permanent marker pen (Mette, C. EU Project guideline personal communication, 2008). The traced transparency was labelled and used to calculate the area which was done as follows:

- The used transparency was cleaned from other dirty and only the traced line was left to appear and then weighed (W1, g)
- Then the length and width of the transparency was measured so as to calculate the area of the whole transparency (length x width (mm) = A1 mm^2
- The area of LD that was traced /marked on the transparency was then cut by a pair of scissors and weighed (W2, g).
- The area of the LD (A2, mm^2) = (A1 mm^2) * (W2, g)/ (W1, g)

3.3.7 Assessment of meat quality parameters

3.3.7.1 Preparation of meat samples

Meat quality measurements were performed on the Longissimus dorsi (LD) muscle excised from the left side of the carcass. The LD muscle from the 7th to the 13th rib was removed 48 hrs post-mortem. From each rear end of the LD muscle, a sample of 2 cm thick, equivalent to 120 g was cut and labelled for determination of drip loss (Honikel, 1998; Otte and Chilonda, 2002). The remaining piece was used for assessment of shear force. A total of three pieces (7 cm long) were cut along the fibre direction from the remaining LD muscles, labelled and sealed in polythene bags for further tests.

3.3.7.2 Determination of Drip loss

From the cut LD piece 2 x 3x 1 cm, the associated adipose tissue or parts of *M. spinalis* and *M. multifidus* were carefully removed from the sampled piece but leaving the facia around the muscle. Immediately the sample was weighed and a length of thin string was threaded through the top of the muscle sample and the sample was placed inside a plastic net. The net was used to prevent the meat from touching the inside of the plastic bag to avoid dripping by capillary action. A plastic bag of standard weight and dimension was drawn up around the netted muscle slice with the string protruding from the open end. The bags were inflated by mouth and tied tightly around the supporting string. The bag with samples (2 x 3 x 1 cm) was then suspended in a chilling room (1 ± 2°C) for the next 48 hrs. At the end of the storage period the muscle samples were removed from all the bags and nets, gently blotted with dry paper towel and weighed. Drip loss was calculated as the loss in weight of the muscle sample and was expressed in percentage of the initial sample weight.

3.3.7.3 Shear force, thawing and cooking loss determination

The three pieces of LD muscle were aged for intervals of 2, 10 and 20 days. A peace of 2 days ageing was taken 48 h post-mortem (pm) and sealed using normal sealer and frozen -20°C. The other two pieces were kept in the chilling room at 0 to 4°C and further aged for 8 and 18 days that is 10th and 20th days after slaughter respectively. After the completion of each ageing time, each sample was taken from the chilling room and transferred to the freezer until analysed.

Meat toughness was determined using the Warner-Bratzler Shear Force (WBSF) machine (Zwick/Roell Z2.5, Germany). The meat pieces to be assessed for shear force were weighed and then thawed for 12 h at 4 °C and re-weighed. The difference was the thawing loss. Each sample was opened, wiped with clean tissue paper, weighed and re-sealed with vacuum pack machine. The samples were then heated at 75 °C for 1 h in a circulating water bath. Cooking was arrested by placing samples in cold tap water which had been flowing for about 2 h. The tap water was left flowing on top of the container with samples for 2 h until the samples were thoroughly cooled. Cold samples were opened and muscle juice inside was removed. The samples were wiped with clean tissue paper and then weighed and the weight was recorded to calculate the cooking loss. Four rectangular shaped blocks (1 x 1 x 5 cm) were cut and each block was sheared three times perpendicular to the muscle fibre direction with rectangular-shaped shear blade attached to Zwick/Roell (22.5 Germany) instrument. The average of 12 shear values represented the WBSF force value for a sample of LD aged for 2, 10 or 20 days. The Zwick was set with 1 kN load cell, with a crosshead speed of 200 mm/min. The maximum load required to shear through the sample (WB peak force) was determined. The detailed procedure for sample preparation, thawing and cooking losses assessment, and shearing is presented in Appendix 3. Plate 6 shows the WBSF machine connected to the operating software.

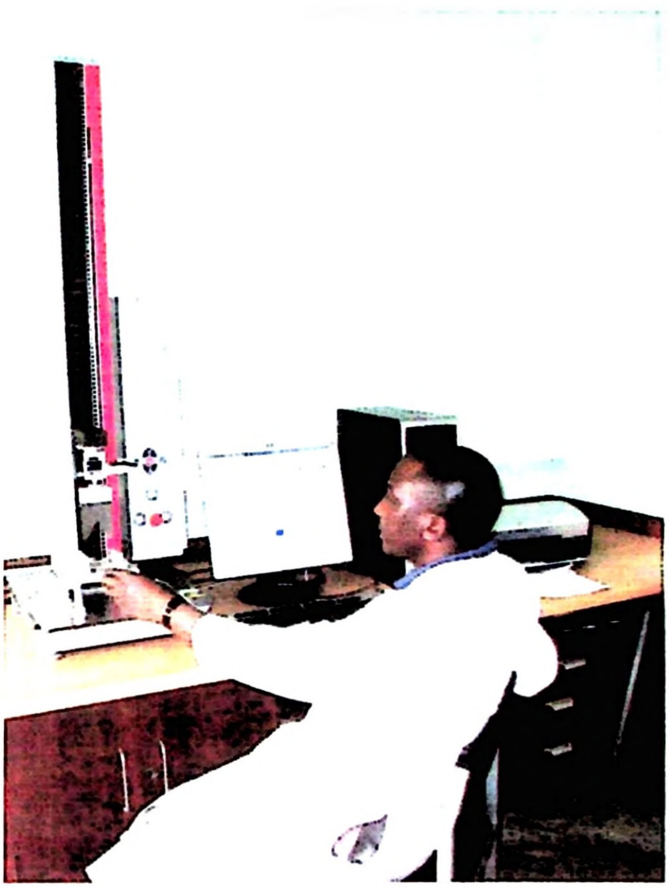


Plate 6: A researcher operating Warner-Bratzler Shear Force (WBSF) machine (Zwick/Roell Z2.5, Germany) for measuring meat tenderness

3.3.8 Determination of forage mass and botanical composition

Forage sampling was performed in three major paddocks, which formed a grazing area for the experimental animals in dietary treatment Graz+C00 and Graz+C50. The size of the grazing area allocated to the experimental animals was estimated to be 9 ha.

Estimation of forage mass (kg/ha) was performed three times during the experimental period, at the beginning, 30th and 60th day from the start of the experiment. Forage mass was assessed by clipping herbage at a height of 1-1.5 cm above ground using a pair of secateurs in 58 randomly placed 0.25 m^2 quadrants in the entire grazing area (Reppert *et al.* 1962). The clipped forage samples from each point were immediately weighed using a spring balance and packed in dry paper bags. The samples from each sampling unit were then air dried for 25 days. After drying the samples were again weighed. The average dry weight of samples per quadrant was then used to calculate the forage mass of the fresh air dry matter per hectare.

Forage mass was estimated by using the formula:

Forage mass (kg DM/ha) = Average air dry weight (kg) X 10,000 m^2)/ Area of a quadrant in metres (0.25 m^2)...........(1)

The forage mass was determined three times in each experiment to obtain the trend on available forage (kg DM/ha). The air dried samples were further transported to the National Livestock Research Institute (NLRI), Mpwapwa for dry matter determination. The samples from the entire grazing area were then ground hammer mill of 1 mm sieve and the samples were thoroughly mixed to obtain representative samples. Thereafter, the samples were transported to the Department of Animal Science and Production (DASP) at Sokoine University of Agriculture (SUA) for chemical analysis.

Forage botanical composition was estimated in two established transect lines along and across the entire grazing area. Forage botanical composition was performed once at the start of each experiment. Sampling was done by placing a 0.25 m^2 quadrant on ground at 10 metres interval in each transect line. A total of 35 and 26 quadrants were sampled along and across the two transects established in the grazing area prior to inception of the experiment. Forage specie frequency was calculated by counting the number of times the individual species had appeared in each thrown quadrant. Percentage frequency was obtained by dividing the number of frequency of each species observed in all the quadrants with total number of frequency of all observed species from all the quadrants for the whole grazing area. The forage identification was facilitated by a local experienced botanist from National Livestock Research Institute (NLRI), Mpwapwa.

3.3.9 Determination of chemical composition of feeds

Chemical composition of grazed forages, grass hay, maize meal, cotton seed cake (CSC) and concentrate mixture were assessed for dry matter, ash, crude protein, cell wall components and *in vitro* digestibility. Dry matter (DM), crude protein and ash contents were analysed according to the recommended procedure of AOAC (2000). The cell wall components of the forages were analysed according to Goering and Van Soest (1991) procedure which included neutral detergent fibre (NDF) which was ash free using sodium sulphate solution and acid detergent fibre (ADF). In evaluating the *in vitro* digestibility of feeds, the two stage technique developed by Tilley and Terry (1963) was used.

3.3.10 Statistical model and data analysis

Data were analysed using General Linear Model (GLM) and Mixed Model procedures of Statistical Analysis System (SAS, 9.2; 2002). The significant differences between treatments were compared using the PDIFF option of SAS (9.2). Covariance analysis (within breed) was used to correct for the variation in initial body weight for animal performance parameters. The models used were as follows:

1. Model: Feed Intake and Feed Conversion Ratio

The first model was the feedlot feed intake and feed conversion ratio which included the fixed effect of the breeds and diet levels as treatments and the interaction of the main effect and the random error.

Model $Y_{ijk} = \mu + A_i + B_j + (AB)_{ij} + e_{ijk}$..(2)

Y_{ijk} = measurement of a unit pen (animal group)

μ = Overall mean ; A_i = effect of i^{th} breed

B_j = effect of j^{th} dietary treatments

$(AB)ij$ = interaction of i^{th} breed and j^{th} dietary treatments

e_{ijk} = random error

2. Model: Animal weight gain and carcass characteristics

The model for weight gain, carcass and non carcass characteristics included the fixed effects of breed, finishing diet and their interactions and the random error. Initial body weights of the animals were used as covariate.

Model $Y_{ijk} = \mu + A_i + B_j + (AB)_{ij} + b(x_{ijk}-\overline{x}) + e_{ijk}$............................(3)

Y_{ijk} = measurement of an individual animal

μ = Overall mean; A_i = effect of i^{th} breed

B_j = effect of j^{th} dietary treatment

$(AB)ij$ = interaction of i^{th} breed and j^{th} dietary treatment ;

$Xijk$ = the record of the live weight of individual

$\overline{X}$ = mean of Individual initial body weight

b = regression of Y_{ijk} on x_{ijk}; e_{ijk} = random error

3. Model: Effect of breed, diet and ageing on meat quality parameters

In analysing the data, the model for meat ageing included the fixed effects of breed, dietary treatments, time of ageing, interaction of the main effects and the random error.

Model $Y_{ijkl} = \mu + A_i + B_j + C_k + (AB)_{ij} + (AC)_{ik} + (BC)_{jk} + (ABC)_{ijk} + e_{ijkl}$.....(4)

Y_{ijkl} = measurement of unit meat sample of individual animal

μ = Overall mean; A_i = effect of i^{th} breed

B_j = effect of j^{th} dietary treatment

C_k = effects k^{th} time of ageing

$(AB)ij$ = interaction of i^{th} breed and j^{th} dietary treatment ;

$(AC)ik$ = interaction of i^{th} breed and k^{th} time of ageing;

$(ABC)ijk$ = interaction of i^{th} breed, j^{th} dietary treatment and k^{th} ageing time; e_{ijkl} = random error

Random statement for the animal was included to account for repeated measurement, covariance structure was compared symmetry.

3.3.11 Financial analysis of fattening cattle

3.3.11.1 Estimation of Net returns of fattening cattle

Net returns was estimated to assess the financial viability of finishing cattle based on the various finishing diets. The Net returns (NR) were meant to determine the profitability of the various finishing treatments while the Gross margins (GM) were intended to measure the profitability with which variable inputs could be converted into outputs. The main input costs used in the calculation of returns included fixed costs and running costs. Fixed costs were limited to the feedlot structure, animal crush constructed for animal handling and a simple feed store. Fixed costs were calculated as annual equivalent values for fixed assets using a simple straight line depreciation method assuming a 10% salvage value and useful life of ten years. Annual depreciation was then converted to the 90 days feeding period. There were no interest charges included because the money used was not borrowed. Running costs included purchased cattle, purchased feeds, labour costs, veterinary drugs and services provided to the animals and transportation costs. Labour cost considered was for herding the grazing animals and labour for general animal care and management. Labour costs were estimated with respect to monthly wages for minimum salary scale and the extra labour for feeding feedlot animals. Labour for experimental data collection and measurements were not included. Transportation costs included ferrying the animals from the market place to the feedlot site and ferrying finished animals to the slaughter house were the same for all the treatment. The revenue was calculated considering the normal market price used for a kilogram of carcass at meat shops (butchery) while selling the carcass at the end of each experiment. Total Net Returns were therefore computed as follows:

Net returns (NRs) =Total revenue (TR) – Total costs (TC)..............................(5)

Whereas, TC = Total variable costs (TVC) + Total Fixed costs (TFC).

Gross margin (GM) =TR– TVC..(6)

The NRs were calculated for each treatment with the assumption that cattle maintain uniform growth rates throughout the experimental period. Estimated NRs under varying prices of selling the quality beef were calculated. The price sensitivity analysis was conducted using three hypothetical selling prices of the finished meat Tshs 3500/=, Tshs 5500/= and Tshs 7000/= per kilogram of carcass. The hypothetical prices used were based on some current prices found in the supermarkets for imported quality steaks which ranged from Tshs 5,000 and Tshs 30,000 per kg of a particular steak or meat cut.

3.4 EXPERIMENT 2: Finishing Cattle During the Dry Season

The main aim of this experiment was to evaluate the effects of breeds of cattle (TSHZ and Boran) and three different dietary treatments on performance, carcass and meat characteristics during the dry season and examine the effect of meat ageing on meat tenderness. It was apparent that the wet season had a confounding effect on the growth performance of animals on Graz+C00 and animals on Graz+C50 which had the lowest amount of concentrate supplement. Hence the need to take into consideration season effects in feedlot trials.

3.4.1 Experimental design and treatments

A total of seventy two (72) steers composed of thirty six (36) Boran and 36 TSHZ were randomly allocated to three dietary treatments in a 2 X 3 factorial experiment in a completely randomized design (CRD). The three dietary treatments were grazing alone (Graz+C00) as control, grazing plus 50 % *ad libitum* concentrate intake (Graz+C50) and *ad libitum* hay intake and *ad libitum* concentrate intake (Hay+C100). Animal in Graz+C50 and Hay+C100 were placed in 3 pens per dietary treatment. Each pen was used as an experimental unit for feed intake and individual animal was considered as an experimental unit on weight changes, carcass and meat quality analysis.

3.4.2 Source of experimental animals and management

The source and management of experimental animals was as described under Expt. 1 except that the animals were of different age and weight. The age range for Boran was 2 to 3 years and average initial liveweight was 225 kg while TSHZ aged ranged from 3 and 4 years and average initial liveweight was 117 kg. The feedlot structure (Plate 1) used in Expt. 1 was also used for Expt. 2. Animals were randomly allocated to dietary treatments after blocking them to initial liveweight groups. Animals on feedlots were housed in twelve pens each pen having four animals.

A preliminary period of 15 days was followed by experimental period of 90 days whereby animals on Graz+C00 and animals on Graz+C50 were grazing in the same paddock used in Expt. 1. Those on Graz+C50 were taken to their respective pens in the evening. Concentrate used in Expt. 1 was given to animals under Graz+C50 depending on the amount consumed by animals on Hay+C100 in that day. All animals in Hay+C100 were given liberal supply of hay and concentrate until ad libitum intake was attained.

3.4.3 Feeds, ration formulation, feeding and management

The source of feeds, ration formulation, feeding methods and management employed were similar to those used in Expt. 1.

3.4.4 Feed intake and body weight measurements

The procedure similar to Expt. 1 was followed on feed intake measurements. The computation for feed intake and weighing of animals and the calculation for average daily gain were similar to Expt. 1.

3.4.5 Slaughtering of experimental animals and taking measurements

3.4.5.1 Slaughtering procedure

At the end of experimental period, animals were taken for slaughter at Dodoma abattoir. Twenty four animals were slaughtered each day on the 87th, 90th, and 93rd day. Therefore on average the fattening period lasted for 90 ± 3 days. The schedule for slaughtering, carcass measurements, and sampling of LD muscle and dissection of 6th rib joint are presented in Appendix 4. The animals for slaughter were picked from each dietary treatment and breed randomly and transported to the abattoir. The animals were fasted for 13 - 15 h prior to slaughter. Other slaughtering procedures at abattoir handling of the carcasses were similar to those used in Expt. 1.

3.4.5.2 Other carcass and meat measurements procedures

All the non-carcass components, carcass weight, derived carcass measurements. linear carcass measurements and measurements of meat quality parameters were measured using similar procedures as in Expt. 1.

3.4.6 Determination of forage mass and forage botanical composition

Forage sampling was performed in the paddocks grazed by the animals. The same methods and techniques for estimating forage mass, and forage botanical composition used in Expt. 1 was followed.

3.4.7 Determination of chemical composition of feeds

The standard procedure used for determination of chemical composition of feeds in Expt. 1 was also employed in Expt. 2.

3.4.8 Statistical model and data analysis

In analysing the data, the three models used in Expt. 1 was also employed in Expt. 2.

3.4.9 Financial analysis of fattening cattle

The Net returns and Gross margin estimation considering the input and output relationship was estimated as done in Expt. 1.

CHAPTER FOUR

4.0 RESULTS

4.1 Results for Experiment 1:Finishing Cattle During Wet Season

This section presents results from Expt. 1, where the response of two breeds of cattle (Tanzania Shorthorn zebu (TSHZ) and Boran) was tested for five different dietary treatments during the rainy season.

4.1.1 Forage mass and nutritive values of feeds used

The major dominant species were *Aristida adescionsis* (16%), *Dactylocterium aegyptium* (13%), *Cenchrus ciliaris* (12%), *Macrotyloma uniflorum* (11%), *Urochloa trichopus* (10%) and others (38%) (Appendix 5). The few identified perennial palatable species were *Cenchrus ciliaris* and *Chloris virgata*. The grazed paddocks had some browse tree species sparsely distributed, including *Acacia tortilis, Albizia spp.* and *Commiphora spp.*

Table 11 gives the mean forage mass of grazed pastures and values of chemical composition for the grazed pastures, hay and the concentrate diet used in Expt. 1. Forage mass increased from 750 kg DM/ha at the beginning (December 2007) to 2240 kg DM/ha at the end of experiment (March, 2008). At the start of the experiment, the natural pastures had high dry matter (DM) and neutral detergent fibre (NDF) contents and these declined slightly to the end of experiment. Low values (41 g/kg DM) of crude protein (CP) content were observed from the forages sampled at the beginning of the experiment and in the subsequent monthly sampling, CP values increased with time reaching a peak of 117 g/kg DM for the sample that was taken at the end of March 2008. The estimated ME contents of the forages increased slightly from 9 to 10 ME MJ/kg

DM. The hay used had high DM content (936 g/kg hay), low crude protein content (49 g/kg DM) and low values of *in vitro* digestible organic matter (*IV*DOM) (418 g/kg hay) with 6.6 ME MJ/kg DM.

Table 11: Forage mass (kg DM per ha) of grazed pasture and Chemical composition of forage, hay and concentrates mixture in Expt.1

Type of feed	Mass kg DM/ha	DM g/kg	Composition (g/kg DM) CP	NDF	ADF	ASH	*Iv*DOM (g/kg DM)	ME (MJ/ kg DM)[1]
Grazed pastures:								
Nov/Dec07	750	560	41	741	467	88	553	8.8
January 2008	1610	518	73	569	344	90	576	9.2
February 2008	1870	486	99	552	289	117	625	10.1
March 08	2240	359	117	449	255	110	563	9.0
Mean	1618	481	83	578	341	101	579	9.3
Roughages:								
HAY 1 – Dec07		935	55	747	474	70	408	6.5
HAY 2–March 08		937	44	780	453	67	418	6.7
Mean		936	50	764	464	69	413	6.6
Concentrate:								
Concentrate mix		823	135	216	51	62	825	13.2
Maize meal		895	95	280	21	11	756	12.1
Cotton seed cake		918	252	391	263	53	734	11.7

[1]Estimates ME MJ/kg DM = 0.016 DOM (McDonald *et al.*, 2002).

4.1.2 Growth performance and feed intake

The treatment effects of breed and diet on growth performance and feed intake of cattle are presented in Table 12. LSMeans for the main effects are given in Appendix 6. The differences between diets on the average initial liveweight (ILW) were not significant (P>0.05). However, the ILW of Boran steers was significantly (P<0.0001) higher (168 vs. 99 kg) than TSHZ. Boran had higher (P<0.001) final liveweight (FLW) (241 vs. 162 kg) and gained more weight (74 vs. 63 kg) and had higher average daily gain (ADG) (736 vs. 623 g/d) than TSHZ. Steers fed on Hay+C100 had the highest (P<0.05) FLW (218 kg) followed by those on Graz+C50 (206 kg). Steers on Graz+C50 had higher (P<0.05) FLW than those on Graz+C00. However, the mean FLW of steers on Graz+C50 (206 kg) was not different (P>0.05) from those on Hay+C80 (203 kg). The pastures were better feed in all aspects than the hay (Table 12). Steers fed on Graz+C00 (195 kg) outperformed those fed on Hay+C60 (186 kg). Steers on Hay+C100 had higher ADG (833 g/d), followed by those on Graz+C50 (717 g/d), Hay+C80 (672 g/d), Graz+C00 (624 g/d) and lastly those on Hay+C60 (552 g/d).

Mean values of feed intake for steers fed under feedlot condition (Hay+C60, Hay+C80 and Hay+C100) are also presented in Table 12. Boran had higher (P<0.0001) total DM intake (6.9 kg/d) than TSHZ (5.7 kg/d). The DMI as percent of liveweight was higher in TSHZ (3.5 %) than Boran (2.9 %). Boran steers had slightly (P<0.05) higher FCR (9.8) than TSHZ (8.9). Steers on Hay+C60 had highest intake of hay and least intake of concentrate. There was significant interaction between breed and diet on hay intake, concentrate intake, ADG TDMI and ME MJ/ kg gain.

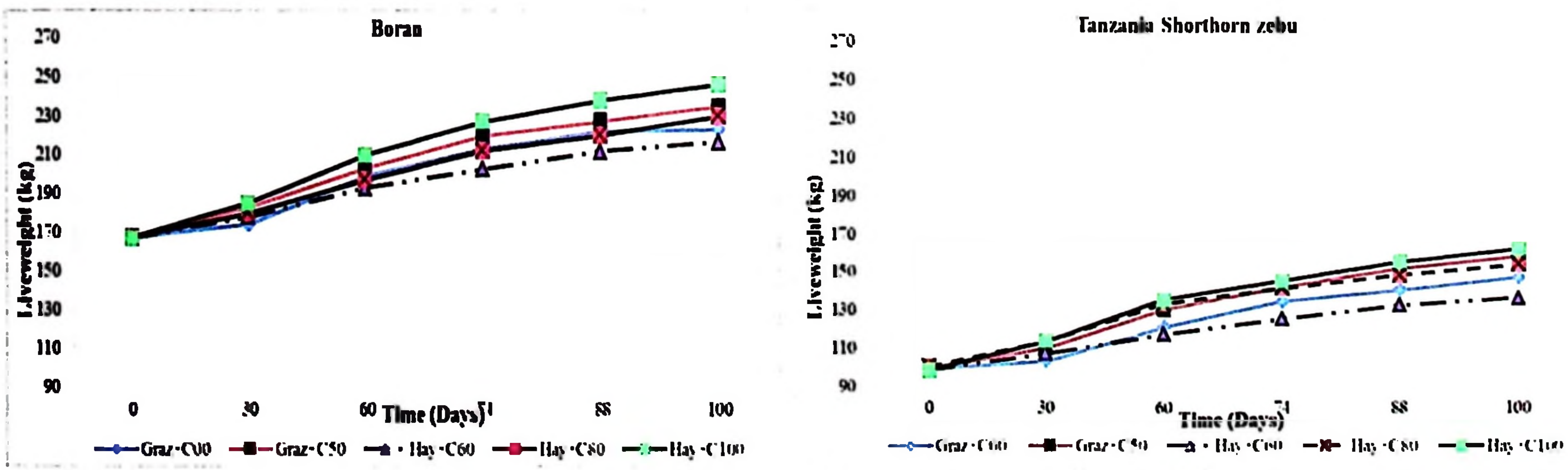
Table 12: LSMeans of the effects of breed and diet treatments and their interaction on growth performance hay and concentrate intake, feed and intake in Expt. 1

Parameter	Boran					Tanzania shorthorn zebu					SEM	P - Value		
	Graz+C00	Graz+C50	Hay+C60	Hay+C80	Hay+C100	Graz +C00	Graz+C50	Hay+C60	Hay+C80	Hay+C100		B	D	B*D
No. of animals	12	12	12	12	12	12	12	12	12	12	-	-	-	-
Feeding, day	100	100	100	100	100	100	100	100	100	100	-	-	-	-
Initial LW (kg)	168	168	167	168	169	98	100	95	104	99	3.1	<.0001	0.6440	0.7420
Final LW (kg)	237^{b}	248^{a}	224^{c}	245^{ab}	255^{a}	154^{c}	163^{c}	149^{e}	162^{c}	180^{d}	5.0	<.0001	<.0001	0.7852
Weight gain (kg)	69^{bc}	80^{a}	59^{cde}	76^{ab}	85^{a}	56^{de}	65^{cd}	54^{e}	58^{d}	81^{a}	3.6	<.0001	<.0001	0.1966
ADG (g/day)	685^{b}	805^{a}	568^{c}	768^{ab}	854^{a}	563^{c}	631^{b}	535^{c}	576^{b}	812^{a}	40.7	<.0001	<.0001	0.0242
Feed Intake (kg / head/day)														
Hay	-	-	2.2	1.9	1.5	-	-	2.0	1.4	1.3	0.03	<.0001	<.0001	<.0001
Concentrate	-	2.7	4.4	5.0	6.0	-	1.9	3.1	4.2	5.0	0.04	<.0001	<.0001	<.0001
TDMI	-	-	6.6	6.9	7.5	-	-	5.1	5.6	6.3	0.05	<.0001	<.0001	<.0001
ME MJ/ kg gain	-	-	127	104	99	-	-	106	120	96	6.5	0.6071	0.0161	0.0242
DMI as % LW	-	-	3^{b}	2.8^{b}	2.8^{b}	-	-	3.6^{a}	3.4^{a}	3.6^{a}	0.03	<.0001	0.3061	0.6223
FCR (kg feed/ kg gain)	-	-	11.5^{a}	9.2^{bc}	8.5^{c}	-	-	10.0^{b}	8.6^{c}	8.0^{d}	0.5	0.0265	0.0001	0.4361

^{abcde} LSMeans with different superscripts in the same row are significantly different (P<0.05). *P*-value =Probability values; SEM = Standard error of mean; Graz+C00 =grazing alone as control; Graz+C50= grazing + 50 % *ad libitum* concentrate intake; Hay+C60, Hay+C80 and Hay+C100 = (*ad libitum* hay + 60, 80 and 100 % of the *ad libitum* concentrate intake respectively) B = Breed; D = Diet; B*D Interaction; LW = Bodyweight; ADG = Average daily gain; TDMI = Total dry matter Intake; DMI= Dry matter intake; and FCR = Feed conversion ratio.

On overall perspective steers fed Hay+C100 had highest total DM intake (6.8 kg/d) followed by Hay+C80 (6.3 kg/d). However, the differences were not significant. Steers on Hay+C100 were the most ($P<0.05$) efficient in feed conversion (kg feed/kg gain) followed by those on Hay+C80 and least for those on Hay+C60.

The pattern of weight changes with time as influenced by dietary treatment for Boran and TSHZ breeds of cattle is illustrated in Figure 5. The trends of weight changes brought by dietary treatments were similar between the two breeds. The weight of the animals increased sharply in the first 30 days for all the diets but this increase was less pronounced in steers on Graz+C00 and Hay+C60. After 60 days, there were clear differences between diets from different dietary treatments. Generally steers on Hay+C100 were superior in daily weight gains throughout the experimental period and therefore attained relatively higher final liveweight at the end of the experiment. Despite the differences in initial body weight, the two breeds gained similarly but at a different magnitude throughout the fattening period, Boran having higher ADG (736 vs. 623 g/d) than the TSHZ.



Graz+C00 =grazing alone as control; Graz+C50= grazing + 50 % *ad libitum* concentrate intake; Hay+C60, Hay+C80 and Hay+C100 = (*ad libitum* hay + 60, 80 and 100 % of the *ad libitum* concentrate intake respectively)

Figure 5: Liveweight changes of Boran (left) and Tanzania shorthorn zebu (right) steers on different diets in Expt. 1

4.1.3 Effects of breed and diet on killing out characteristics in Expt. 1

Table 13 gives the LSMeans of the main effects of breed and diet on killing out characteristics, non carcass components and their relative percentages to the liveweight. The LSMeans for the treatments and the interactions of the main effects are given in Appendix 7. Boran steers were slaughtered at a heavier (P<0.05) liveweight, hence higher (P<0.05) empty liveweight (ELW) and hot carcass weight (HCW) than TSHZ. Irrespective of breed, ELW and HCW increased with increasing amount of concentrate on offer, except for treatment Hay+C60 which showed lower values than animals on Graz+C50. Overall steers on Graz+C50 performed (P<0.05) better than those that received Hay+C60 in most parameters studied. Steers on Hay+C100 had heavier HCW followed by Graz+C50, Hay+C80 and Graz+C00 and had highest dressing percentage (DP), followed by Hay+C80 and Graz+C50. The mean DP ranged from 49 to 52 % between breeds and 49 to 55 % between the dietary treatments.

Fig. 6 presents trends in DP for both Boran and TSHZ as affected by amount of concentrate supplementation. The DP was higher in Boran than TSHZ in all treatment and tended to increase with concentrate intake.

Table 13: LSMeans for the main effects of breed and diet on killing out characteristics, non carcass components and their proportions in Expt. 1

Parameter	Breed (B)				Dietary treatment (D)						*P – Value*	
	Boran	TSHZ	SEM	*P - Value*	Graz+C00	Graz+C50	Hay+C60	Hay+C80	Hay+C100	SEM	*D*	B*D
Number of observations	60	60	-	-	24	24	24	24	24	-	-	-
Weight (Kg)												
FLW	241^{a}	162^{b}	1.2	<.0001	195^{c}	206^{b}	186^{d}	203^{bc}	218^{a}	2.9	<.0001	0.7852
ELW	227^{a}	148^{b}	1.9	<.0001	177^{c}	185^{b}	177^{c}	193^{ab}	205^{a}	0.9	<.0001	0.5467
Hot carcass weight	127^{a}	81^{b}	2.3	<.0001	98^{b}	105^{b}	94^{b}	102^{b}	120^{a}	3.6	<.0001	0.9918
Dressing percentage (%)	52^{a}	49^{b}	0.9	0.0257	49^{b}	50^{b}	49^{b}	52^{ab}	55^{a}	1.5	0.0361	0.6790
Non carcass components (kg)												
Gut content	15.2^{a}	13.5^{b}	0.8	0.0497	18.6^{a}	17.1^{ab}	11.0^{c}	11.5^{c}	13.6^{bc}	2.9	<.0001	0.0287
Pluck	8.7^{a}	6.5^{b}	0.2	<.0001	7.4^{ab}	7.8^{a}	6.6^{b}	7.5^{ab}	8.6^{a}	0.3	0.0002	0.5135
Kidney	0.6^{a}	0.4^{b}	0.02	<.0001	0.4^{b}	0.5^{ab}	0.4^{b}	0.5^{ab}	0.6^{a}	0.03	0.0209	0.4212
Mesenteric fat	5.1^{a}	3.8^{b}	0.2	<.0001	3.0^{d}	3.8^{cd}	4.3^{bc}	4.5^{b}	6.5^{a}	0.3	<.0001	0.9440
Total fat	7.5^{a}	5.5^{b}	0.3	<.0001	4.5^{d}	5.6^{cd}	6.2^{bc}	6.9^{b}	9.5^{a}	0.4	<.0001	0.8947
Proportions (%) FLW												
Gut content	14^{b}	17^{a}	0.6	<.0001	18.0^{a}	16.3^{ab}	13.9^{c}	14.5^{bc}	15.4^{bc}	0.7	<.0001	0.0561
Pluck	3.6^{b}	4.0^{a}	0.13	0.0165	3.8^{a}	3.8^{a}	3.5^{b}	3.7^{ab}	3.9^{a}	0.17	0.0209	0.3102
Kidney	0.2	0.2	0.05	0.8206	0.2	0.2	0.2	0.3	0.2	0.23	0.2626	0.8721
Mesenteric fat	2.1^{b}	2.3^{a}	0.07	0.0169	1.5^{c}	1.8^{bc}	2.3^{b}	2.2^{b}	3.0^{a}	0.08	<.0001	0.6728
Total fat	3.1^{b}	3.4^{a}	.3	0.0025	2.3^{c}	2.7^{bc}	3.3^{b}	3.4^{b}	4.4^{a}	0.1	<.0001	0.3467

[abcde] LSMeans with different superscripts are significantly different ($P<0.05$). *P*-value =Probability values; Graz+C00 = grazing alone as control; Graz+C50 = grazing + 50 % *ad libitum* concentrate intake; Hay+C60, Hay+C80 and Hay+C100 = (*ad libitum* hay + 60, 80 and 100 % of the *ad libitum* concentrate intake respectively); Standard error of mean (SEM); Tanzania shorthorn zebu (TSHZ); Final liveweight (FLW) and Empty liveweight (ELW).

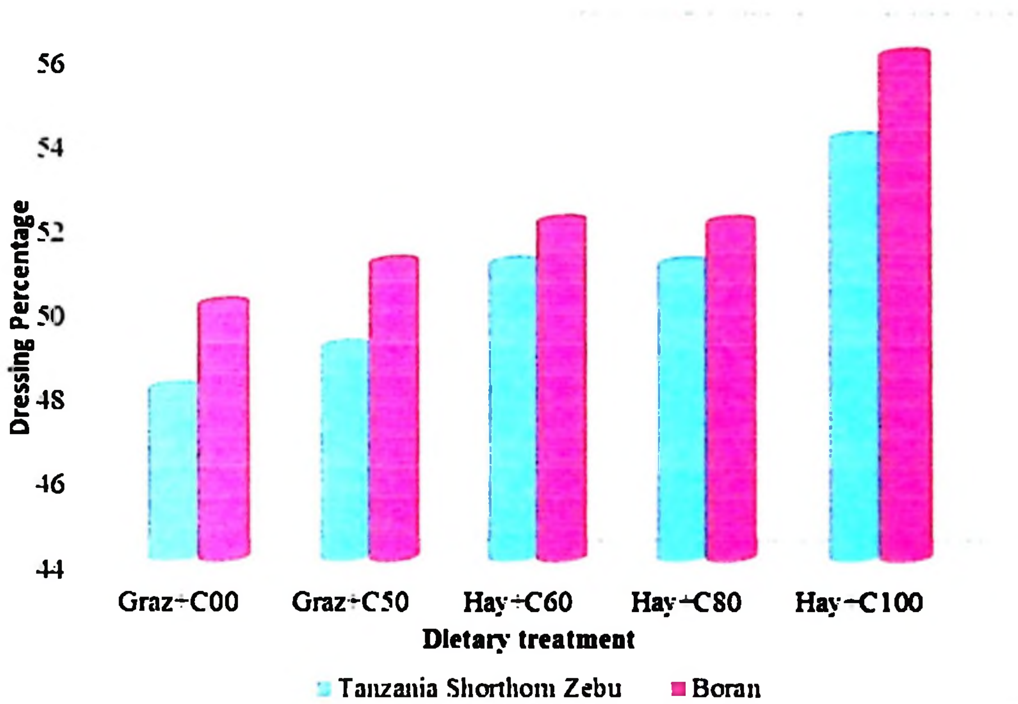


Figure 6: Dressing percentage (DP) of Boran and TSHZ steers in Expt. 1 as influenced by dietary treatments

Boran steers had higher ($P<0.05$) weights of pluck, gut content, mesenteric fat and the total trimmed fat than TSHZ. Expressing these parameters as a percent final liveweight however, the values were significantly ($P<0.05$) higher in TSHZ than Boran. Diets had significant effect ($P<0.05$) on pluck weights, kidney, mesenteric fat and total trimmed fat. There was no clear trend as far as pluck and kidney weights were concerned while amount of total fat increased with concentrate intake. Gut content decreased with amount of concentrate on offer. When expressed as % FLW, gut content was significantly higher with grazing animals (Graz+C00 and Graz+C50) than those under feedlot condition (Hay+C60, Hay+C80 and Hay+C100).

The mean proportions of mesenteric fat and total fat to FLW increased with concentrate supplementation.

The results indicated that the mean proportions of gut content to FLW persistently declined with increased concentrate intake in both Boran and TSHZ steers (Fig. 7.).

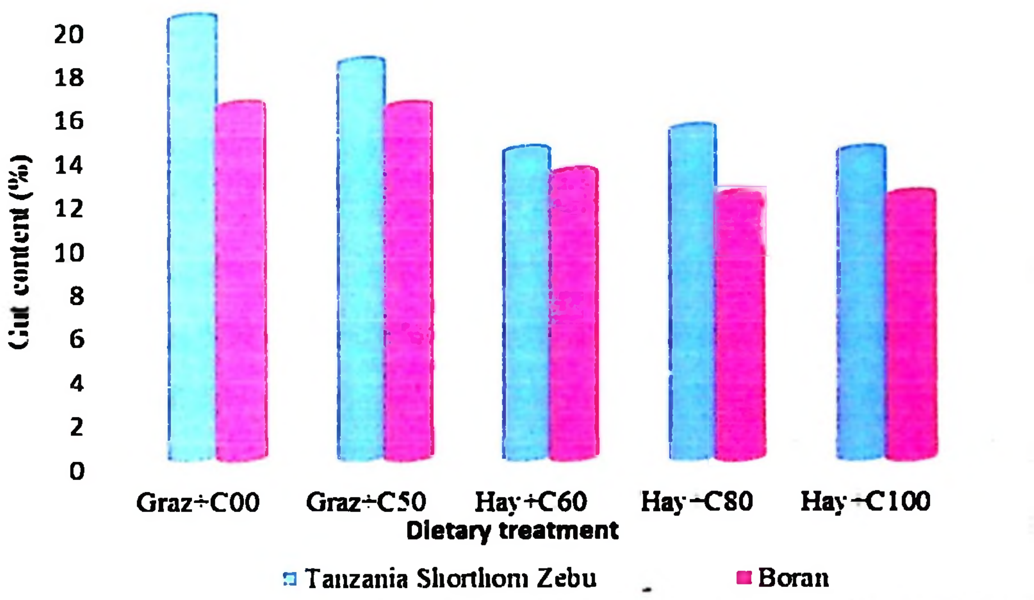


Figure 7: Values of gut content as percent of the FLW of Boran and TSHZ

4.1.4 Carcass linear measurements and classification

Table 14 gives the LSMeans for the main effects of breed and diet on carcass linear measurements and classification. The LSMeans for the individual treatment effects are presented in Appendix 8. Average carcass length, chest depth, limb circumference and fat thickness of Boran carcasses were higher ($P<0.05$) than those for TSHZ. Diets did not affect ($P>0.05$) carcass length and limb circumference. Carcass chest depth, however was affected ($P<0.05$), where carcasses from animals on Hay+C100 had highest length (57 cm) compared to those from animals on Hay+C80 and Graz+C50 which both had chest depth of 53 cm. Carcass fatness and back fat layer increased with increasing concentrate intake. Carcasses from Hay+C100 had the highest fat thickness and back fat layer in the two breeds (4.1: 1.3 cm for Boran and 3.1: 1.5 cm for TSHZ). Although breed had no significant difference (P>0.05) on *Longissimus dorsi* (LD) area, Boran carcasses had larger (39 cm^2) LD area than TSHZ (32 cm^2). Carcasses from Hay+C60 had the smallest (P<0.05) LD area (25 cm^2), whereas Hay+C100 had the largest (50 cm^2).

Breed and diets significantly (P<0.05) affected carcass conformation. Boran scored higher (9) than TSHZ (7) on carcass conformation (P<0.05). On average, carcasses from animals on Hay+C100 had the highest conformation score for Boran (10) compared to that of TSHZ (8). There was no breed differences (P>0.05) on carcass fatness and meat colour. The values for carcass fatness increased with the increased in amount of concentrate intake while that of meat colour decreased.

Meat colour in carcasses from grazed animals (Graz+C00 and Graz+C50) had higher (P<0.05) scores (4.4 and 4.1 classified as dark yellow and a little dark respectively) compared to those under feedlot (Hay+C60, Hay+C80 and Hay+C100) with score 3.1 and 2.8 both classified as normal respectively.

Table 14: LSMeans for the main effects of breed and diet on carcass linear measurements and classification in Expt. 1

Parameter	Breed				Dietary treatment						*P - Value*	
	Boran	TSHZ	SEM	*P - Value*	Graz+C00	Graz+C50	Hay+C60	Hay+C80	Hay+C100	SEM	D	B*D
Number of observations	60	60	-	-	24	24	24	24	24	-	-	-
Carcass measurements (cm)												
Carcass length	105^{a}	97^{b}	1.7	<.0001	101	103	97	98	102	2.7	0.5039	0.9881
Carcass chest depth	57^{a}	50^{b}	1.0	<.0001	52^{b}	53^{ab}	51^{b}	53^{ab}	57^{a}	1.6	0.0489	0.9350
Limb circumference	68^{a}	56^{b}	1.4	<.0001	66	60	59	62	67	2.1	0.1096	0.5219
Fat thickness	3.1^{a}	2.4^{b}	0.1	<.0001	2.3^{c}	2.4^{c}	2.5^{bc}	2.9^{b}	3.6^{a}	0.2	<.0001	0.7621
Back fat	1.0	1.0	0.2	0.5300	0.9^{b}	0.9^{b}	0.9^{b}	1.0^{b}	1.4^{a}	0.3	<.0001	0.3470
LD area (cm^2)	39	32	0.3	0.0975	29^{b}	38^{ab}	25^{b}	na	50^{a}	4.2	0.0004	0.7880
EUROP classification score												
Carcass conformation	8.6^{a}	6.9^{b}	0.1	<.0001	7.1^{c}	7.5^{bc}	7.7^{b}	7.8^{b}	8.6^{a}	0.2	<.0001	0.6757
Carcass fatness	3.7	3.3	0.1	0.1490	3.0^{d}	3.3^{cd}	3.5^{bc}	3.8^{ab}	4.0^{a}	0.1	<.0001	0.9817
Carcass meat colour	3.52	3.54	0.1	0.3334	4.4^{a}	4.1^{a}	3.1^{b}	3.1^{b}	2.8^{b}	0.1	<.0001	0.6246

[abcde] LSMeans with different superscripts are significantly different ($P<0.05$). *P*-value = Probability values; Graz+C00 =grazing alone as control; Graz+C50= grazing + 50 % *ad libitum* concentrate intake; Hay+C60, Hay+C80 and Hay+C100 = (*ad libitum* hay + 60, 80 and 100 % of the *ad libitum* concentrate intake respectively); Standard error of mean (SEM); Tanzania shorthorn zebu (TSHZ); Longissimus dorsi (LD) and na = not analysed

4.1.5 Composition of the 6th rib joint in Expt. 1

There was no breed and diet interaction effects on 6th rib joint composition (Appendix 9). The proportion of lean meat in the 6th rib joint for Boran (64 %) was lower (P<0.05) than that of TSHZ (67 %) while percentage composition of fat was higher (P<0.05) for Boran (18 %) than that of TSHZ (16 %) as presented in Table 15. Boran had higher proportion of bone (18%) than TSHZ (17 %) although the difference was not significant (P>0.05). Animals with heavier weights (Graz+C50 and Hay+C100) had higher proportion of fat in the carcass than their counterparts. The ratio of lean to fat was higher (P<0.05) in TSHZ (4.8 vs. 3.8) than that of Boran. Lean to fat ratio decreased with increased concentrate supplements in the diets. Neither breed nor diets influenced the ratios of lean to bone and fat to bone.

Table 15: LSMeans for the main effects of breed and diet on carcass composition from the 6th rib joint in Expt. 1

Parameter	Breed				Dietary treatment					*P* - *Value*	
	Boran	TSHZ	SEM	*P* - *Value*	Graz+ C00	Graz+C50	Hay+ C60	Hay+ C100	SEM	D	B*D
Number of observations	60	60	-	-	24	24	24	24	24	-	-
Weight of 6th rib joint (kg)	1.8^{a}	1.3^{b}	0.06	<.0001	1.5	1.6	1.4	1.6^{a}	0.08	0.2001	0.9163
Percent composition in 6th rib joint											
Lean	63.9^{b}	66.9^{a}	0.8	0.0110	66.6	66.7	65.0	63.4	1.13	0.1675	0.4995
Fat	17.7^{a}	15.5^{b}	0.63	0.0152	13.8^{c}	15.7^{bc}	16.9^{b}	20.1^{a}	0.88	0.0001	0.2083
Bone	18.4	17.4	0.56	0.3451	19.6	17.7	18.1	16.5	0.79	0.0912	0.7113
Ratios of 6th rib joint components											
Lean: fat	3.8^{b}	4.8^{a}	0.22	0.0037	5.3^{a}	4.4^{b}	3.9^{bc}	3.4^{c}	0.32	0.0006	0.1249
Lean: bone	3.5	5.0	0.87	0.2293	3.5	3.8	3.6	3.9	1.24	0.5508	0.5492
Fat: Bone	1.0	1.1	0.15	0.6015	0.7	0.9	1.0	1.2	0.22	0.2903	0.3330
(Lean + Fat):Bone	4.5	4.8	0.1	0.2	4.2	4.8	4.7	5.0	0.31	0.1342	0.2142

^{abc}LSMeans with different superscripts are significantly different (P<0.05). *P*-value = Probability values; Standard error of mean (SEM); Graz+C00 =grazing alone as control; Graz+C50= grazing + 50 % *ad libitum* concentrate intake; Hay+C60 and Hay+C100 = (*ad libitum* hay + 60 and 100 % of the *ad libitum* concentrate intake)

4.1.6 Meat quality characteristics

4.1.6.1 Post-mortem (pm) Temperature changes on Longissimus dorsi (LD)

There was no significant interaction (P>0.05) between breed and diet on the rate of fall of temperature on LD pm and therefore, main effects of breed and diet were presented (Figure 8 and 9 respectively).

LSMeans for treatments and the interactions effects are presented in Appendix 10. Temperature for Boran carcasses was higher than that of TSHZ at all recording periods except at 48 h pm. Temperature decline on LD muscle differed (P<0.05) between Boran and TSHZ by 1.9°C, 0.9°C and 0.9°C at 45 minutes pm, 6 h pm and at 24 h pm respectively. Temperature fall (Tdrop1) from 45 minutes to 6 h pm and from 6 h to 24 h pm (Tdrop2) were similarly higher (P<0.05) for Boran carcasses than those of TSHZ. Temperature readings on LD pm were highest in animals on Hay+C100 than for other treatments in all the measurements recorded.

There was a tendency for carcasses from high concentrate diets (Hay+C60 and Hay+C100) to retain more heat than those from other dietary treatments. The rate of fall of temperature (Tdrop1) was highest (12.8 °C) in LD from grazing animals and lowest (11.4°C) in LD from carcasses on *ad libitum* concentrate intake (Hay+C100). Opposite results were however observed on Tdrop2.

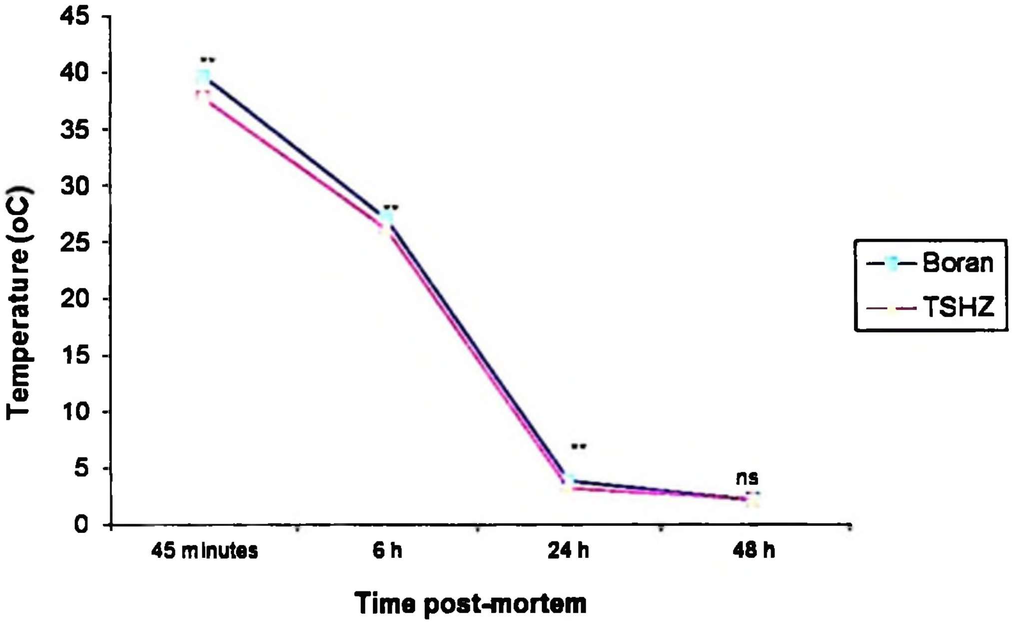


Figure 8: Effects of breed on temperature changes of *Longissimus dorsi* (LD) muscle in Expt. 1

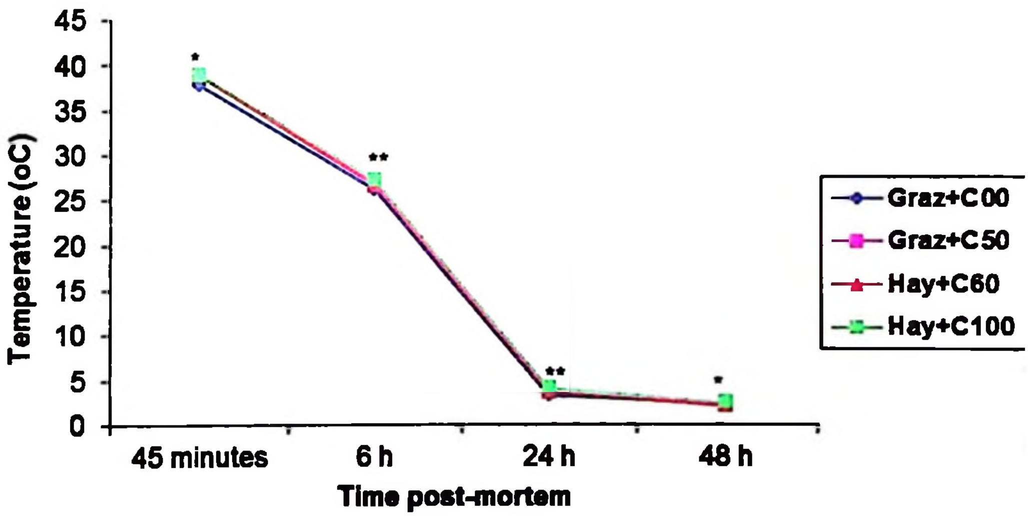


Figure 9: Effects of diet on temperature changes of *Longissimus dorsi* (LD) muscle in Expt. 1

4.1.6.2 Changes in pH of LD muscle post-mortem in Expt. 1

LSMeans on the main effects of breed and diet on post-mortem pH of the LD muscle is presented in Figure 10 and 11 respectively. LSMeans for treatments and interaction effects are shown in Appendix 11. There was no breed effect (P>0.05) on pH changes of LD muscle from the slaughtered steers at 45 minutes, 6 and 24 h pm. However, the values of pH of LD muscle at 48 h pm and pHchange1 were higher (P<0.05) for Boran than TSHZ. At 6 h pm the mean pH value of LD of carcasses from grazed animals (Graz+C50 and Graz+C00) were significantly higher (P<0.05) than those on other treatments. At 48 h pm the ultimate pH values ranged from 5.64 for Graz+C00 to 5.66 for Hay+C100. Diet significantly affected (P<0.05) pHchange1 where it was highest for LD under Graz+C00. The pH readings at 45 minutes pm were highest and ranged from 6.29 - 6.37. There was significant (P<0.05) interaction effect between breed and diet on pH values at 6 h pm. The tendency was for the pH of LD muscle pm to decrease (P<0.05) with increase in the amount of concentrate intake, thus LD muscle of carcasses from dietary treatment Hay+C100 had lowest pH value (5.70) and those from Graz+C00 had the highest pH value (5.98). The ultimate pH at 48 h pm of LD from Boran and TSHZ ranged from 5.6 – 5.7. There was no evidence for diet differences at ultimate pH (48 h) of LD muscle.

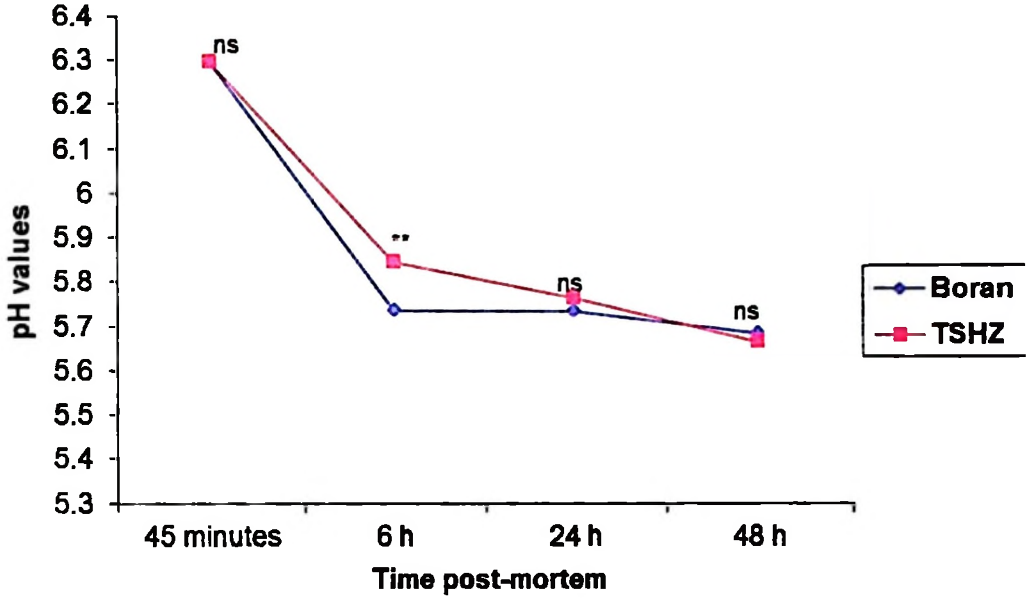


Figure 10: Effects of breed on pH changes of *longissimus dorsi* (LD) muscle post-mortem in Expt. 1

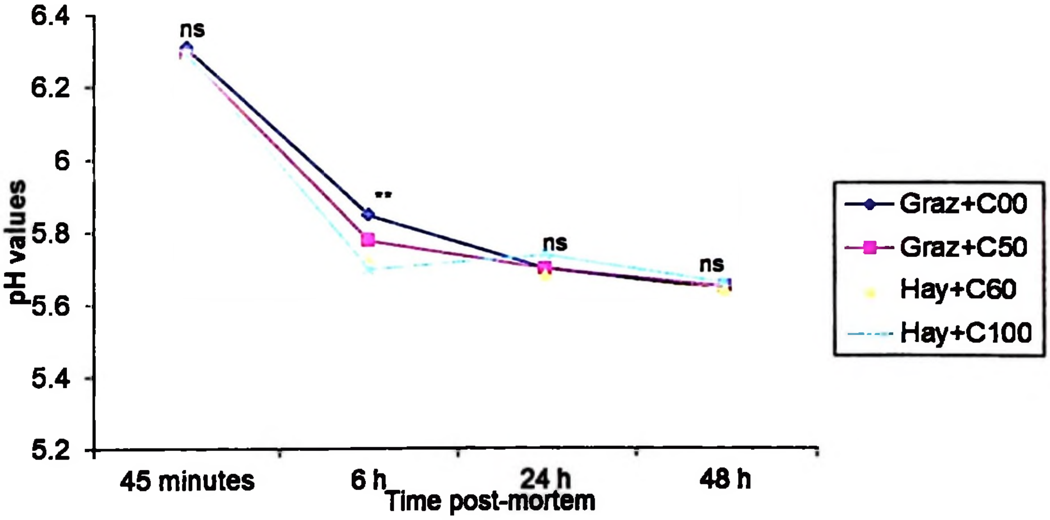
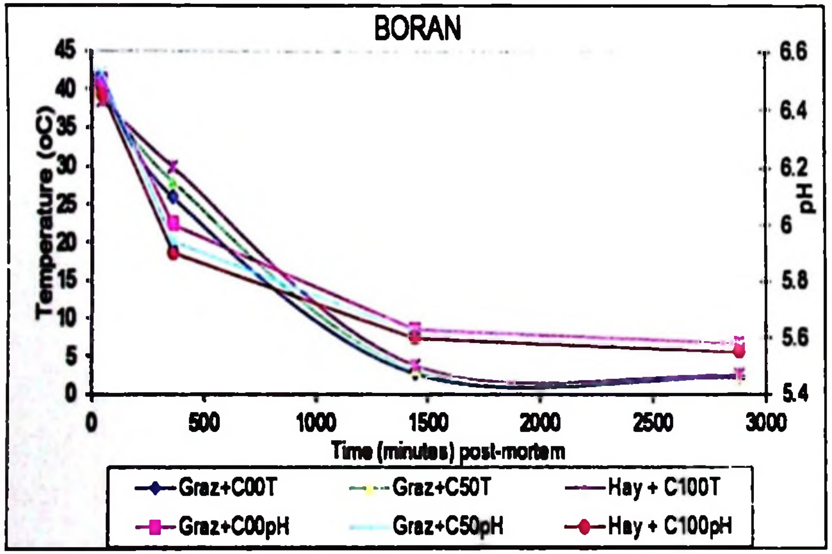


Figure 11: Effects of diet on pH changes of *longissimus dorsi* (LD) muscle post-mortem in Expt. 1

The interrelationship between temperature, pH and time of LD muscle in Boran and TSHZ for each dietary treatment is shown in Fig. 12. Temperature and pH readings on LD muscle from both Boran and TSHZ carcasses on average were 22.5 °C and pH 6, respectively. The temperature and pH readings declined to almost stable at ultimate 48 h pm and the LD muscle at ultimate temperature and pH values ranged 2.0 - 2.5 °C and 5.67 – 5.71, respectively for Boran, and 2.1 – 2.5 °C and 5.60 – 5.64, respectively for TSHZ. In both breeds, there was a relationship between temperature fall and pH changes with time as shown in Fig. 12. There was drastic fall in both temperature and pH of LD muscle from 45 min to 6 h and stabilizing at 24 to 48 h pm.



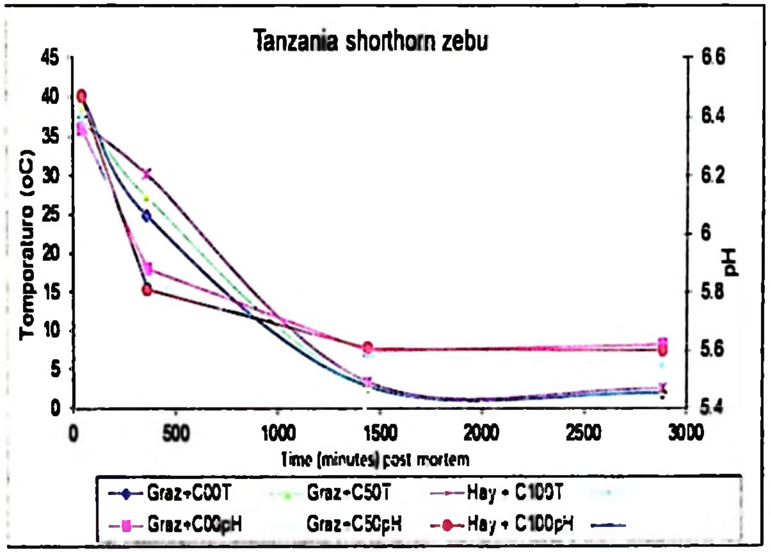


Figure 12: Post-mortem temperature decline and pH changes on LD muscle from Boran and TSHZ on different diets in Expt.1

4.1.6.3 Effects of breed, diet and ageing time on meat quality attributes in Expt. 1

Table 16 shows LSMeans of the main effects of breed and diet on drip loss, thawing loss, cooking loss and shear force of LD muscle from Boran and TSHZ. Effects of the individual treatments on drip loss, thawing loss, cooking loss and shear force are given in Appendix 12. There was no breed effect (P>0.05) observed for drip and thawing (P>0.05) losses. The highest (P<0.05) drip loss (5.7%) was observed in carcasses produced from animals on Graz+C00 and lowest value (2.7%) in those on Hay+C60. Thawing losses decreased with increasing concentrate level and the lowest value (4.1 %) was on dietary treatment Hay+C100. Cooking loss was higher (P<0.05) in TSHZ than Boran but there was no dietary effect. The overall mean values of the shear force ranged from 42 to 60 N. TSHZ had higher (P<0.05) mean WBSF value (52 N) than those from Boran (48 N). The grazing animals had higher (P<0.05) mean shear force value (60 N) and the values decreased with increasing level in concentrate intake with *ad libitum* concentrate diet having the lowest mean shear force value (42 N). There was no significant interaction (P>0.05) between breed, diet and ageing time on the parameters measured on meat quality attributes.

Table 16: LSMeans of the main effects of breed and diet on percentage drip loss, thawing loss, cooking loss and shear force on LD muscle in Expt. 1

Parameter	Drip loss (%)	Thawing loss (%)	Cooking loss (%)	Shear force (N)
	Meat quality attributes			
Breed (B)				
No of obs.	32	32	32	32
Boran	4.0	4.5	24.5^{b}	47.5^{b}
TSHZ	4.1	4.7	27.1^{a}	51.7^{a}
SEM	0.5	0.6	0.5	1.4
P-value	0.4864	0.4431	0.0006	0.0386
Dietary treatments (D)				
No of obs.	16	16	16	16
Graz+C00	5.7^{a}	5.1^{a}	26.5	60.2^{a}
Graz+C50	4.3^{b}	4.9^{ab}	27.1	50.7^{b}
Hay+C60	2.7^{c}	4.3^{bc}	26.3	45.8^{c}
Hay+C100	3.5^{bc}	4.1^{c}	24.6	41.8^{c}
SEM	0.5	0.3	0.7	2.0
P-value	<.0001	0.0392	0.2363	<.0001
P-value B*D	0.7701	0.9810	0.9608	0.1667

^{abc} LSMeans with different superscripts in the same column on specific parameter are significantly different (P<0.05). *P*-value = Probability values: Standard error of mean (SEM); Graz+C00 = grazing alone as control: Graz+C50= grazing + 50 % ***ad libitum*** concentrate intake: Hay+C60 and Hay+C100 = (*ad libitum* hay + 60 and 100 % of the ***ad libitum*** concentrate intake respectively)

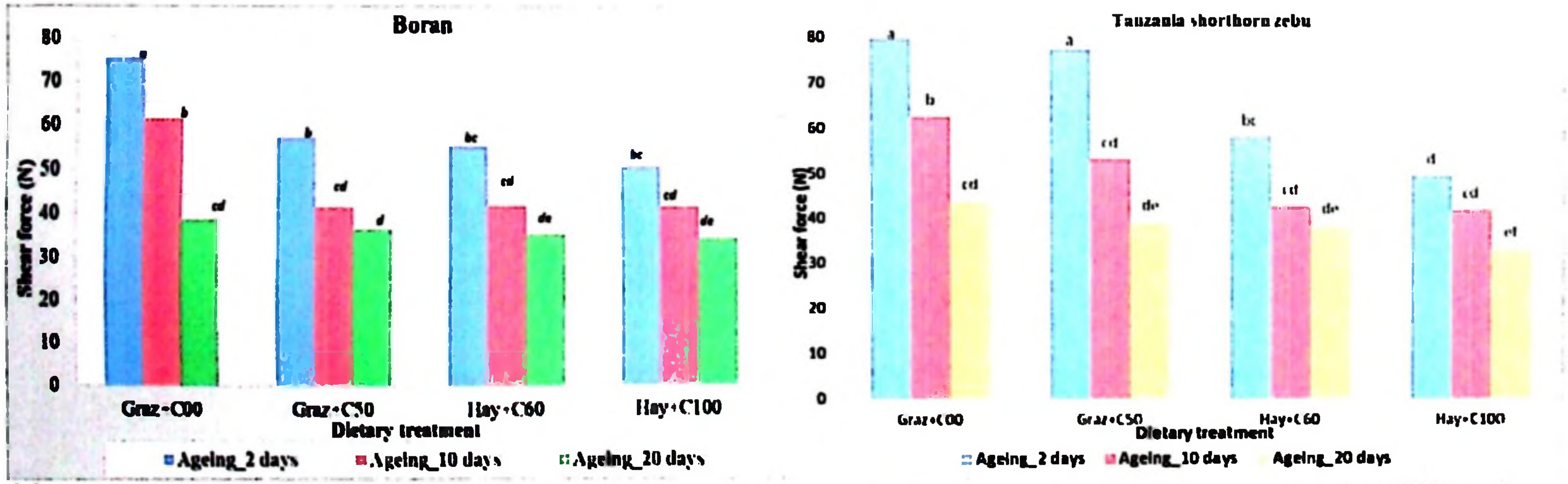
Table 17 gives the LSMeans on thawing loss, cooking loss and shear force on LD muscle as affected by ageing time of the meat. The LSMeans of breed vs. ageing and diet vs. ageing on LD muscle are presented in Appendices 13 and 14. Thawing loss decreased (P<0.05) with increased ageing time. Cooking losses of LD muscle decreased from 26.6 at 2 days to 23.8 % at 20 days although the difference was not significant. The percentage thawing loss decreased (P<0.05) with increasing ageing time from 2 to 10 days by 9 %.

Ageing meat from 2 to 10 days resulted into 22% reduction (P<0.05) in shear force of LD muscle (Table 17). Additional 10 days ageing decreased shear force values by 24%. The rate of decrease in shear force values on LD muscle increased at a decreasing rate. LSMeans of the main effects (breed, diet and ageing time) on shear force of LD muscle from Boran and TSHZ are illustrated in Fig. 13. There were no (P>0.05) interaction effects on shear force values between breed, diets and ageing time. The significant interaction effects (P<0.05) were observed between breed and diet, and diet and ageing time. In all the dietary treatment studied, increasing ageing time decreased (P<0.05) shear force values but the extent of decrease in shear force values depended on the level of concentrate supplementation, with the rate of decline been less in concentrate diets.

Table 17: LSMeans of the main effects of ageing time (days) on percentage thawing loss, cooking loss and shear force on LD muscle in Expt. 1

Parameter	Ageing time (days)				
	2	10	20	SEM	*P-Value*
Thawing loss (%)	5.8[a]	5.1[b]	2.3[c]	0.2	<.0001
Cooking loss (%)	26.6	24.2	23.8	0.6	0.0502
Shear force (N)	62.9[a]	48.7[b]	37.3[c]	1.5	<.0001

[abc] LSMeans with different superscripts in the same row are significantly different (P<0.05). P-value = Probability values; SEM= Standard error of mean.



[abcde] LSMeans with different superscripts between bars chart are significantly different ($P<0.05$). Graz+C00 =grazing alone as control; Graz+C50= grazing + 50 % *ad libitum* concentrate intake; Hay+C60 and Hay+C100 = *ad libitum* hay + 60 and 100 % of the *ad libitum* concentrate intake respectively.

Figure 13: LSMeans of the main effects of breed, diet and ageing time on shear force (N) of LD muscle from Boran and TSHZ in Expt. 1

4.1.3 Net returns (NRs) of fattening cattle in Expt. 1

Net returns (NRs) of fattening cattle (Boran and TSHZ) under the five dietary treatments used in Expt. 1 are presented in Table 18. The tables also give Net returns from purchasing cattle (i.e. none intervention), slaughtering and selling the carcass directly instead of keeping the animals for 100 days on pasture as the case in Graz+C00. This table is derived from costs of inputs used (Appendix 15), costs for individual treatment (Appendix 16-17) and estimated unit cost of producing one kg of carcass (Appendix 18 and 19). Sensitivity test for estimation of break even point using feed price for the two extreme dietary treatments under Graz+C00 and Hay+C100 for Boran and TSHZ were described in Appendix 20-23. The highest profit was obtained when animals were bought from auction, slaughtered and sold directly in the butchers (non intervention option), net returns being Tshs 92,000 for Boran and Tshs 62500 for TSHZ. Animals on Graz+C00 had also positive net returns; values for Boran were 8 times the NR values for TSHZ. Net returns were negative in all other treatments with values decreasing with increase supplementation. Boran had lower negative net returns than TSHZ in all treatments implying that the losses are more pronounced in TSHZ.

Table 18: Cost and Net returns (Tshs. '000) per head of fattening cattle in Expt. 1

	Dietary treatment					
	None I*	Graz+C00	Graz+C50	Hay+C60	Hay+C80	Hay+C100
Boran						
Cost of animals	198	198	198	198	198	198
Concentrate mix	0	0	60.9	127	136	154
Hay	0	0	0	27.2	23.5	18.6
Pasture/Grazed	0	30.0	30.0	0	0	0
Vet. drugs and services	0	5.8	5.8	5.8	5.8	5.8
Labour (man-days)	0	12.7	16.6	22.7	22.7	22.7
Transportation	10.0	20.0	20.0	20.0	20.0	20.0
Total variable costs	208	267	331	373	383	401
Fixed costs	0	0	13.0	13.0	13.0	13.0
Total Cost	208	267	344	386	396	414
Total Revenue	300	300	320	293	318	355
Gross margin	92.0	33.5	-11.3	-80.6	-65.4	-45.5
Net returns 1	92.0	33.5	-24.3	-93.5	-78.4	-58.5
Net returns 2	-	-	103.7	23.5	48.6	83.5
Net returns 3	-	-	359.7	257.5	302.6	367.5
Net returns 4	-	-	551.7	432.9	493.1	580.5
Tanzania Shorthorn zebu						
Cost of animals	115	115	115	115	115	115
Concentrate mix	0	0	42.9	94.7	112	129
Hay	0	0	0.0	24.8	17.3	16.1
Pasture/Grazed	0	30.0	30.0	0	0	0
Vet. drugs and services	0	5.8	5.8	5.8	5.8	5.8
Labour (man-days)	0	12.7	16.6	22.7	22.7	22.7
Transportation	10.0	20.0	20.0	20.0	20.0	20.0
Total variable costs	125	184	230	283	276	309
Fixed costs	0	0	13.0	13.0	13.0	13.0
Total Cost	125	184	243	296	289	322
Total Revenue	188	188	210	175	195	243
Gross margin	62.5	4.0	-20.3	-108	-80.7	-66.1
Net returns 1	62.5	4.0	-33.2	-121	-93.6	-79.0
Net returns 2	-	-	50.7	-26.2	-15.6	34.1
Net returns 3	-	-	218.7	113.8	140.4	228.1
Net returns 4	-	-	344.8	218.8	257.4	373.6

*None I = control (direct purchase and sell immediately)

4.2 Results for Experiemnt 2

In this section results from experiment (Expt.) 2 are presented to give the response of two breeds of cattle (TSHZ and Boran) that were tested on one fattening diet under feedlot condition compared to grazing and supplementation at 50 % of the *ad libitum* feeding and grazing only as a control during the dry season.

4.2.1 Forage mass and nutritive values of feedstuffs in Expt. 2

Grazing paddocks were the same paddocks as those used in Expt.1. The dominant species during Expt. 2 were *Aristida adescionsis* (20%), *Cenchrus ciliaris* (15%), *Tridax procumbens (13%)*, *Chloris virgata* (4%) and, *Eragrostis pattern* (4%). The rest of the forages/shrubs made up 44% of the total forage. The dominant forage species identified in the area where animals were grazing are presented in Appendix 24.

The mean values of forage mass yield (kg DM/ha) and chemical composition for the grazed pastures, hay, concentrate mixture, maize meal and cotton seed cake are presented in Table 19. Forage mass yield decreased from 830 kg DM/ha at the beginning of the experiment to 455 kg DM/ha at the end of the experiment. Dry matter of fresh samples of grazed pasture ranged from 662 to 867 g/kg forages. Crude protein (CP) content of the forages declined from 52 to 36 g/kg DM with progression of the study. Average values of IVDOM of forages in the grazing paddocks decreased from 561 to 481 g/kg DM. IVDOM of the hay was low (436 g/kg DM) and had ME of 6.9 MJ/Kg DM. The estimated ME of forages in the paddocks declined from 9 in August to 7 (MJ ME /kg DM) in November.

Table 19: Forage mass (kg DM/ha) of grazed pasture and chemical composition of forage, hay and concentrate mixture in Expt. 2

Type of feed	Mass Kg DM/ha	DM g/kg	CP	NDF	ADF	ASH	*IV* DOM	ME (MJ/ kg DM) [1]
			(g /kg DM)					
Grazed pastures								
August 08	830	662	52	744	470	74	561	9
September 08	705	782	45	741	408	82	515	8.2
October 08	612	821	41	690	496	119	480	7.7
November 08	455	867	36	791	522	78	474	7.6
HAY 1 Aug 08	-	931	56	776	467	121	413	6.6
HAY 2 Nov 08	-	933	42	768	458	67	458	7.3
Concentrate mixture	-	826	130	296	52	83	847	13.6
Maize meal	-	887	150	164	25	18	750	12
Cotton seed cake	-	937	282	464	334	52	734	11.7

[1] Estimated ME MJ/kg DM = 0.016 DOM (McDonald *et al.*, 2002).

4.2.2 Growth performance and carcass characteristics in Expt. 2

LSMeans of the main effects of breed and diet on growth performance and feed intake of cattle are shown in Table 20. Individual values (LSMeans) for each treatment and main interactions effects are given in Appendix 25. There was no significant difference (P>0.05) in total live weight gain and ADG between the two breeds, although Boran steers had slightly higher ADG (364 vs. 349 g/day) than TSHZ. Steers fed on Hay+C100 had heavier (P<0.05) FLW (283 kg) compared to the steers on Graz+C50 (229 kg) and steers on Graz+C00 (186 kg). Steers fed Hay+C100 had highest ADG (735 g/day) and hence gained more weight (66 kg) during fattening period followed by those on Graz+C50 (377 g/day; 34 kg). Steers on Graz+C00 were losing weight (-45 g/day; -5 kg).

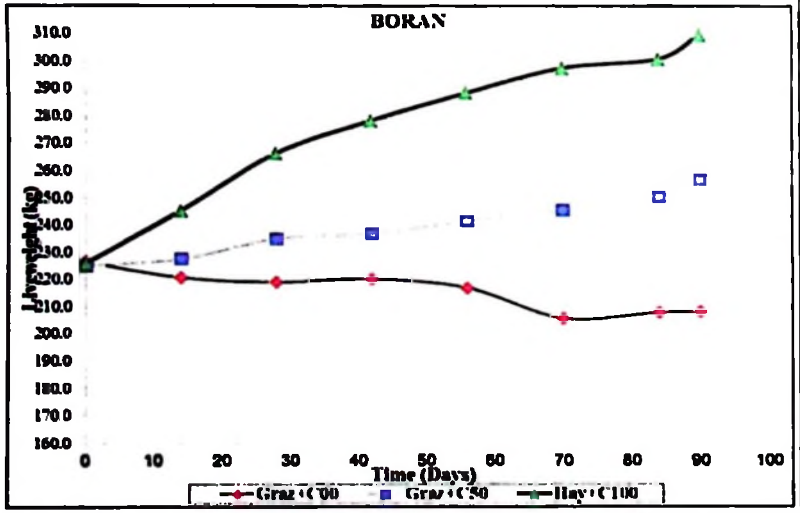
Feed intake as affected by dietary treatment could not be assessed as it was not possible to measure DM intake during grazing for animals on treatments (Graz+C00 and Graz+C50). It was observed that Boran steers on treatment Hay+C100. had higher (P<.05) total DM intake (6.1 vs. 5.7 kg) than TSHZ. There was no differences in feed conversion ratio (11.5 vs. 12.1 kg feed/ kg gain) between Boran and TSHZ (P>0.05). The TDMI was higher (P<0.05) in Boran than TSHZ, but expressing TDMI as percent Liveweight, values were higher (P<0.05) for TSHZ (3.3%) than Boran (2.9).

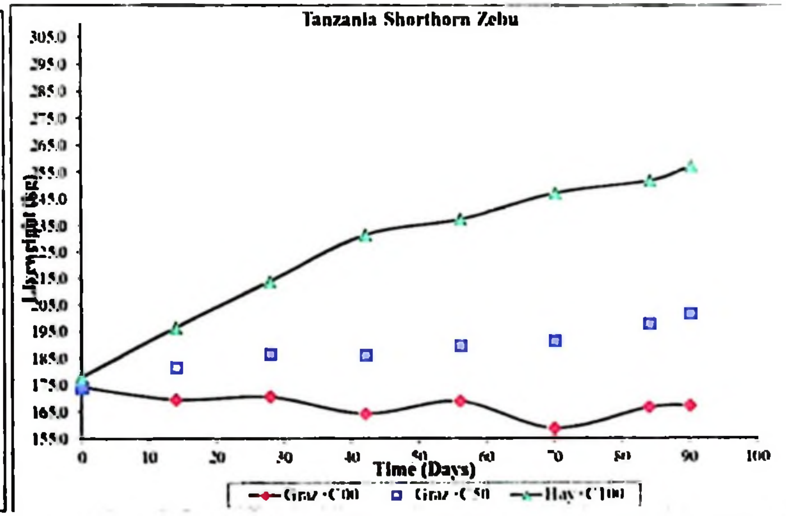
Table 20: LSMeans for the main effects of breed and diet on growth performance and feed intake by cattle in Expt. 2

Parameter	Breed (B)				Dietary treatment (D)				*P - Value*	
	Boran	TSHZ	SEM	*P - Value*	Graz+C00	Graz+C50	Hay+C100	SEM	D	B*D
Number of animals	36	36	-	-	24	24	24	-	-	-
Feeding period, (days)	90	90	-	-	90	90	90	-	-	-
Animal weight (kg)										
Initial Liveweight (ILW)	225^{a}	177^{b}	1.4	<.0001	191	195	217	3.9	0.4938	0.7858
Final Liveweight (FLW)	258^{a}	209^{b}	1.2	<.0001	186^{c}	229^{b}	283^{a}	3.3	<.0001	0.7832
Weight gain	33	32	2.8	0.6180	-5^{c}	34^{b}	66^{a}	1.9	<.0001	0.5602
ADG (g/day)	364	349	16.3	0.5132	-45^{c}	377^{b}	735^{a}	19.9	<.0001	0.1180
Feed Intake (kg/head/day)										
Number of animals	12	12	-	-	-	-	24	-	-	-
Hay Intake	1.2^{a}	1.0^{b}	0.1	<.0001	na	na	2.3	na	na	na
Concentrate intake	4.8	4.7	0.06	0.2060	na	na	6.4	na	na	0.0606
TDMI	6.1^{a}	5.7^{b}	0.05	<.0001	na	na	8.7	na	na	0.6640
ME intake MJ/day	74.4^{a}	71.4^{b}	0.04	<.0006	na	na	103	na	na	0.2860
ME MJ/kg gain	136	137	0.01	0.9506	na	na	137	na	na	0.9910
DMI as % LW	2.9	3.3	0.06	<.0001	na	na	3.1	na	na	0.6440
FCR (kg feed/ kg gain)	11.5	12.1	0.08	0.0861	na	na	11.8	na	na	0.0020

[abc] LSMeans with different superscripts in the same row are significantly different (P<0.05). *P*-value = Probability values; Graz+C00 =grazing alone as control; Graz+C50= grazing + 50 % *ad libitum* concentrate intake; Hay+C100 = *ad libitum* hay + *ad libitum* concentrate intake; SEM = Standard error of mean; TDMI = Total dry matter intake; ADG = Average daily gain; DMI = Dry matter intake per day; LW = Liveweight; FCR kg of feed/ kg of gain and na = not applicable.

Irrespective of breed, animals on Graz+C00 were continuously loosing weight and this loss was very pronounced in the 6th weighing (Fig. 14). The steers fed Hay+C100 were gaining weight at an increasing rate with time. The steers fed on Graz+C50 were intermediate in growth performance irrespective of breed. Conversely, animals on Graz+C00 were losing weight throughout the experimental period attaining lowest final weight at slaughter. Despite the difference in initial body weight, the two breeds gained similar weights throughout the fattening period.





Graz+C00 =grazing alone as control; Graz+C50= grazing + 50 % *ad libitum* concentrate intake and Hay+C100 = *ad libitum* hay + *ad libitum* concentrate intake

Figure 14: Liveweight changes of Boran (left) and Tanzania shorthorn zebu (right) steers in Expt.2

4.2.3 The main effects of breed and diet on killing out characteristics in Expt. 2

Table 21 shows the LSMeans of the main effects of breed and diet on killing out characteristics, non carcass components and their relative percentages to the liveweight. LSMeans for treatments and the main effect interactions are given in Appendix 26. Boran steers had higher FLW, ELW and HCW than TSHZ. Steers fed Hay+C100 had significantly (P<0.05) heavier FLW, ELW and HCW than those on Graz+C50 and Graz+C00. Steers on Hay+C100 had higher DP (54 %) followed by those on Graz+C50 (51 %) and least in those on Graz+C00 (DP (47%). Fig. 15 illustrates treatment effects on dressing percentage (DP). The results indicated that the DP increased with increased levels of concentrate supplementation. There was no difference between breed on DP for animals on treatments Graz+C50 and Hay+C100 but for those on Graz+C00, TSHZ dressed higher than Boran.

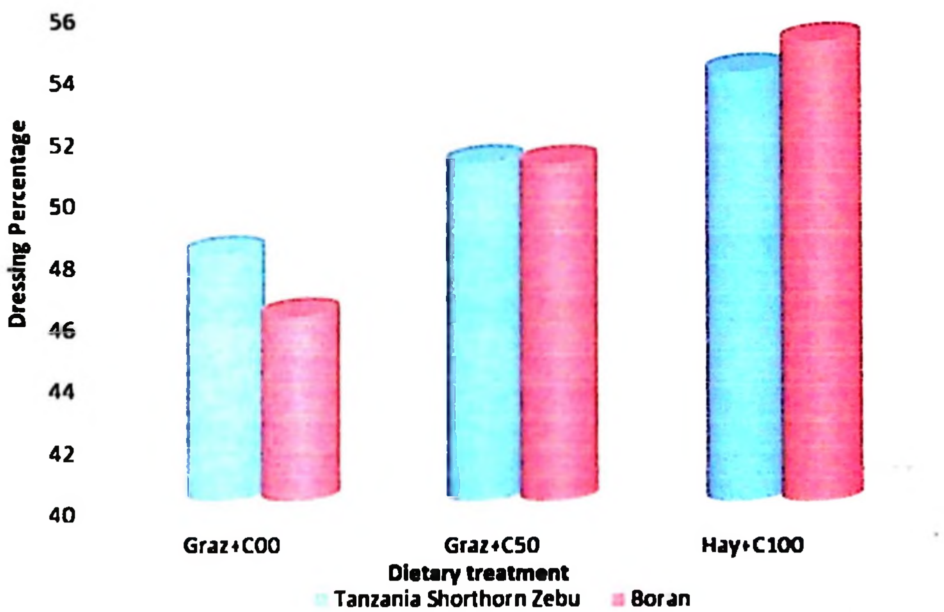


Figure 15: The effects of breed and dietary treatment on dressing percentage of Boran and TSHZ in Expt. 2

The weight of all measured non carcass components were affected significantly ((P<0.0) by breed and diet. Boran steers had heavier pluck weight (12.2 vs. 10.8 kg), mesenteric fat (4.7 vs. 4.0 kg) and total fat (6.4 vs. 5.6 kg) than TSHZ. There was no difference (P>0.05) on the weight of gut content between the breeds although gut content expressed as percent of FLW was higher (P<0.05) in TSHZ than Boran (Table 27). On average the weights of non-carcass components increased with increased in concentrate levels. Significant (P<0.05) difference on weight of gut content was observed between diets where steers on Graz+C00 had the heaviest gut content (18 kg) followed by those on Graz+C50 (16 kg) and Hay+C100 (15).The difference in gut content was more pronounced (P<0.05) between Graz+C00 and Hay+C100 (18 vs.15 kg for Boran and 18 vs. 14 kg for TSHZ). Steers fed on Hay+C100 had the smallest proportion of gut content

(11 % of FLW). Diets had significant effect (P<0.05) on mesenteric and trimmed total fat expressed as percentage of FLW whereby steers fed on Hay+C100 had more proportion of both mesenteric and total fat than those on Graz+C50 and Graz+C00.There was no interaction between breed and diet in any of the measured parameter (Appendix 25). Fig. 16 demonstrates clearly that the proportions of gut content were higher in TSHZ than in Boran and decreased with concentrate intake.

Table 21: LSMeans for the main effects of breed and diet on killing out characteristics, non carcass components and their proportions in Expt. 2

Parameter	Breed				Dietary treatment				*P - Value*	
	Boran	TSHZ	SEM	*P - Value*	Graz+C00	Graz+C50	Hay+C100	SEM	*D*	*B*D*
Weights (kg)										
Final Liveweight	258^{a}	209^{b}	1.2	<.0001	186^{c}	229^{b}	283^{a}	3.3	<.0001	0.7832
Empty Liveweight	242^{a}	192^{b}	6.2	<.0001	174^{c}	208^{b}	269^{a}	4.2	<.0001	0.9230
Hot carcass weight	132^{a}	108^{b}	2.7	<.0001	90^{c}	115^{b}	154^{a}	3.2	<.0001	0.5081
Dressing percentage	51	51	0.9	0.6366	47^{b}	51^{ab}	54^{a}	1.1	<.0001	0.6662
Non carcass components (kg)										
Gut contents	17	16	1.1	0.7797	18^{a}	16^{ab}	15^{b}	0.8	0.0397	0.7542
Pluck	12.2^{a}	10.8^{b}	0.2	<.0001	9.1^{c}	11.0^{b}	14.2^{a}	0.3	<.0001	0.8756
Kidney	0.6	0.5	0.02	0.4160	0.5^{b}	0.5^{b}	0.6^{a}	0.02	0.0016	0.3249
Mesenteric fat	4.7^{a}	4.0^{b}	0.2	0.0369	1.7^{c}	3.6^{b}	7.9^{a}	0.3	<.0001	0.9631
Total fat	6.4^{a}	5.6^{b}	0.3	0.0462	2.3^{c}	4.9^{b}	10.9^{a}	0.4	<.0001	0.9791
Proportions (%) FLW										
Gut content	13^{b}	14^{a}	0.5	<.0001	16^{a}	13^{b}	11^{c}	0.3	<.0001	0.3126
Pluck	4.7	5.2	0.03	0.0524	4.9	4.8	5.0	0.1	0.1640	0.3215
Kidney	0.23	0.24	0.2	0.2416	0.3	0.2	0.2	0.5	0.0712	0.6129
Mesenteric fat	1.8	1.9	0.02	0.1742	0.9^{c}	1.6^{b}	2.8^{a}	0.2	<.0001	0.3291
Total fat	2.5	2.7	0.05	0.0733	1.2^{c}	2.1^{b}	3.9^{a}	0.2	<.0001	0.4432

[abc]LSMeans with different superscripts are significantly different (P<0.05). P-value = Probability values; Graz+C00 =grazing alone as control; Graz+C50= grazing + 50 % *ad libitum* concentrate intake; and Hay+C100 = *ad libitum* hay + *ad libitum* concentrate intake; Standard error of mean (SEM) and Tanzania shorthorn zebu (TSHZ);

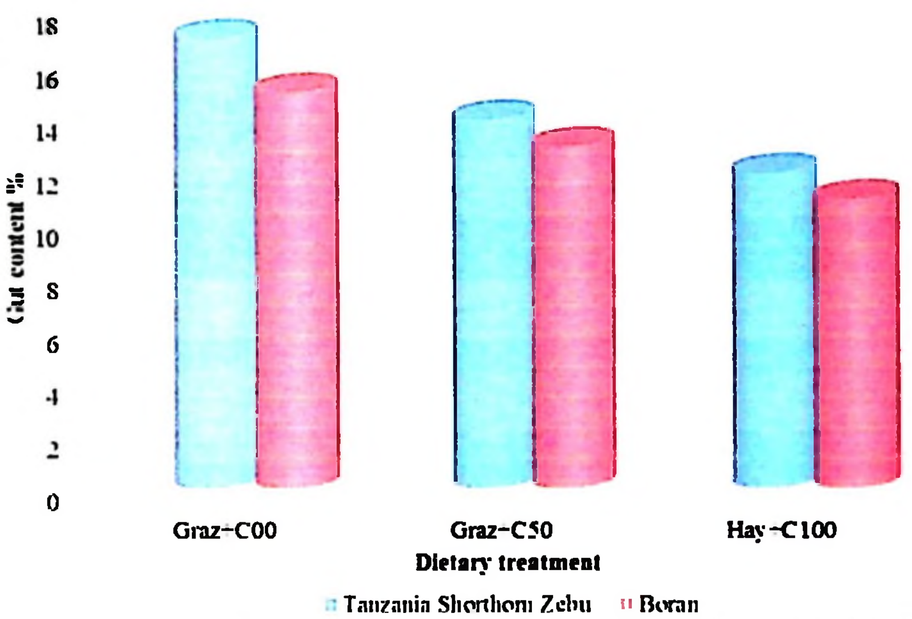


Figure 16: The effects of breed and diet on gut content as percentage of the final body weight of Boran and TSHZ in Expt. 2

4.2.4 Carcass linear measurements and classification in Expt. 2

Table 22 gives LSMeans for the main effects of breed and diet on carcass linear measurements and EUROP carcass classification. LSMeans for the treatments and main interaction effects are presented in Appendix 27. Boran had longer (P<0.05) carcass length (109 vs. 101 cm), bigger limb circumference (67 vs. 59 cm) and LD muscle area (56 vs. 47 cm^2) than TSHZ. There was no significant breed difference (P>0.05) observed in carcass chest depth. In all parameters studied, the tendency was for the carcass measurements to increase with increase in the amount of concentrate supplementation. Breed difference (P<0.05) was observed on carcass conformation (CC) where Boran carcasses scored higher (10) than TSHZ, which scored 9. On average carcasses from Hay+C100 scored 12 on CC and 4 on carcass fatness (CF) values that are higher than those obtained for Graz+C50 (CC = 9; CF = 3) and Graz+C00 (CC = 7; CF = 2). The meat colour (MC) for carcasses from animals on Hay+C100 were normal MC (3) compared to carcass from Graz+C50 and Graz+C00 where both had a dark colour MC (4). Carcass conformation and fat scores, increased while score on meat colour decreased as the amount of concentrate intake increased. There was a significant interaction between breed and diet on back fat thickness (Appendix 27) where back fat thickness was higher for TSHZ fed Hay+C100 (2.2 cm) and lower for those on Graz+C00 (0.5 cm).

Table 22: LSMeans for the main effects of breed and diet on carcass linear measurements and classification in Expt. 2

Parameter	Breed				Dietary treatment				*P - Value*	
	Boran	TSHZ	SEM	*P - Value*	Graz+C00	Graz+C50	Hay+C100	SEM	D	B*D
Carcass measurements (cm)										
Carcass length	109^{a}	101^{b}	1.1	0.0032	103^{b}	104^{b}	108^{a}	1.0	0.0064	0.0647
Carcass chest depth	54^{a}	49^{b}	1.4	0.0775	49^{b}	51^{ab}	54^{a}	1.0	0.0203	0.9126
Limb circumference	67^{a}	59^{b}	1.4	0.0043	58^{c}	62^{b}	70^{a}	1.0	<.0001	0.4558
Fat thickness 10^{th} rib	1.1	1.2	0.2	0.7267	0.6^{b}	0.9^{b}	1.9^{a}	0.1	<.0001	0.7000
Back fat thickness	3.1	2.4	0.3	0.5644	1.7^{c}	2.9^{b}	4.5^{a}	0.2	<.0001	0.0054
LD muscle area (cm^2)	56^{a}	47^{b}	1.6	0.0003	46^{b}	53^{a}	57^{a}	2.0	<.0001	0.6429
EUROP Classification (score)										
Carcass conformation	9.5^{a}	8.8^{b}	0.2	0.0341	6.5^{c}	8.9^{b}	12.1^{a}	0.2	<.0001	0.2154
Carcass fatness	2.7	2.8	0.1	0.5272	1.8^{c}	2.8^{b}	3.8^{a}	0.1	<.0001	0.1240
Carcass meat colour	3.6	3.7	0.1	0.3914	4.4^{a}	3.7^{b}	2.9^{c}	0.1	<.0001	0.7810

[abc]LSMeans with different superscripts are significantly different ($P<0.05$). P-value = Probability values (*P*-value); Graz+C00 = grazing alone as control; Graz+C50= grazing + 50 % *ad libitum* concentrate intake; Hay+C100 = (*ad libitum* hay + *ad libitum* concentrate intake); Standard error of mean (SEM) and Tanzania shorthorn zebu (TSHZ).

4.2.5 Effect of breed and diet on carcass composition

LSMeans for the main effects for breed and diet on composition of 6th rib joint in absolute weight and weight of these tissues as percent of joint weight is shown in Table 23 and for individual treatments and their interactive effects in Appendix 28. The weight and proportion of lean, fat and bone were not affected by breed but affected by dietary treatments ($P<0.05$).The trend was for the values to increase from Graz+C00 to Hay+C100. As expected, diets had no effect ($P>0.05$) on bone weight during fattening. Animals on Hay+C100 had higher ($P<0.05$) percent of fat (19 %) followed by those on Graz+C50 (11%) and Graz+C00 (7%). The difference between breeds on tissue ratios was not significant where as ratios of lean:fat decreased while those of lean: bone and fat: bone increased with levels of concentrate intake.

Table 23: LSMeans for the main effects of breed and diet on carcass composition

Parameter	Breed (B)				Dietary treatment (D)				P-value	
	Boran	TSHZ	SEM	*P – Value*	Graz+C00	Graz+C50	Hay+C100	SEM	*D*	D*B
Number of observations	36	36	-	-	24	24	24	-	-	-
Weight 6th rib joint (kg)	2.1[a]	1.9[b]	0.1	0.0475	1.4[c]	1.9[b]	2.7[a]	0.1	<.0001	0.0200
Weight of 6th rib components										
Lean	1.2	1.1	0.1	0.0691	0.9[c]	1.1[b]	1.5[a]	0.1	0.0006	0.6995
Fat	0.4	0.3	0.01	0.3746	0.2[c]	0.3[b]	0.7[a]	0.01	<.0001	0.8617
Bone	0.5	0.5	0.01	0.7201	0.3	0.5	0.5	0.01	0.0535	0.6119
Percent composition										
Lean	57.1	57.9	2.8	0.4243	64.3	57.9	55.6	3.4	0.2514	0.7861
Fat	19.0	15.8	1.2	0.2087	14.3	15.8	25.9	1.4	0.1290	0.3255
Bone	23.8	26.3	0.1	0.0595	21.4	26.3	18.5	1.1	0.1278	0.7529
Ratios of components										
Lean: Fat	3.0	3.7	0.2	0.9020	4.5	3.7	2.1	0.8	0.0568	0.4321
Lean: Bone	2.4	2.2	0.0	0.5822	3.0	2.2	3.0	0.3	0.9563	0.4755
Fat: Bone	0.8	0.6	0.1	0.8308	0.7	0.6	1.4	0.1	0.2460	0.3867
Lean+Fat/Bone	3.2	2.8	0.2	0.2341	3.7	2.8	4.6	0.2	0.2314	0.4851

[abc]LS*Means* with different superscripts are significantly different ($P<0.05$). *P*-value = Probability values; SEM = Standard error of mean; Graz+C00 =grazing alone as control; Graz+C50= grazing + 50 % *ad libitum* concentrate intake; Hay+C100 = *ad libitum* hay +100 % *ad libitum* concentrate intake)

4.2.6 Meat quality characteristics

4.2.6.1 Post-mortem (pm) temperature changes on Longissimus dorsi (LD) muscle

LSMeans of the main effects of breed and diet on temperature changes on LD muscle of carcasses from Boran and TSHZ are presented in Figure 17 and 18 respectively. Treatment least-square means and their interaction effects are presented in Appendix 29. Temperature at 45 minutes and 6 h pm was higher ($P<0.05$) for Boran than TSHZ. The temperature changes at 24 and 48 h pm and the degree of drop were not affected ($P>0.05$) by breed. The mean values of temperature changes at 45 minutes and 6 h pm increased ($P<0.05$) and those at 24 h pm decreased ($P<0.05$) with increased levels of concentrate intake. The mean values of temperature decline of LD muscle (T drop 1) decreased whereas Tdrop2 increased ($P<0.05$) with concentrate intake. The mean interaction effects between breed and diet was significant ($P<0.05$) at 45 minutes and 6h pm. The tendency was for temperature for Graz+C00 to be higher in Boran (26°C) than TSHZ (24.9°C) but the trend changed with higher concentrate intake (Hay+C100), where temperature of LD muscle was lower but not significant in Boran (30.0°C) than TSHZ (30.2°C).

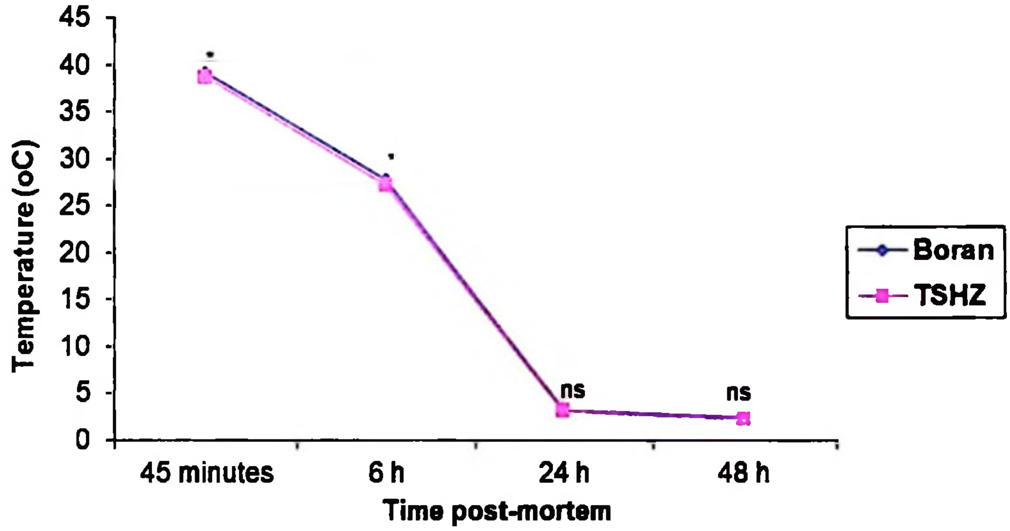


Figure 17: Effects of breed on temperature decline of Longissimus dorsi (LD) muscle from carcasses in Expt. 2

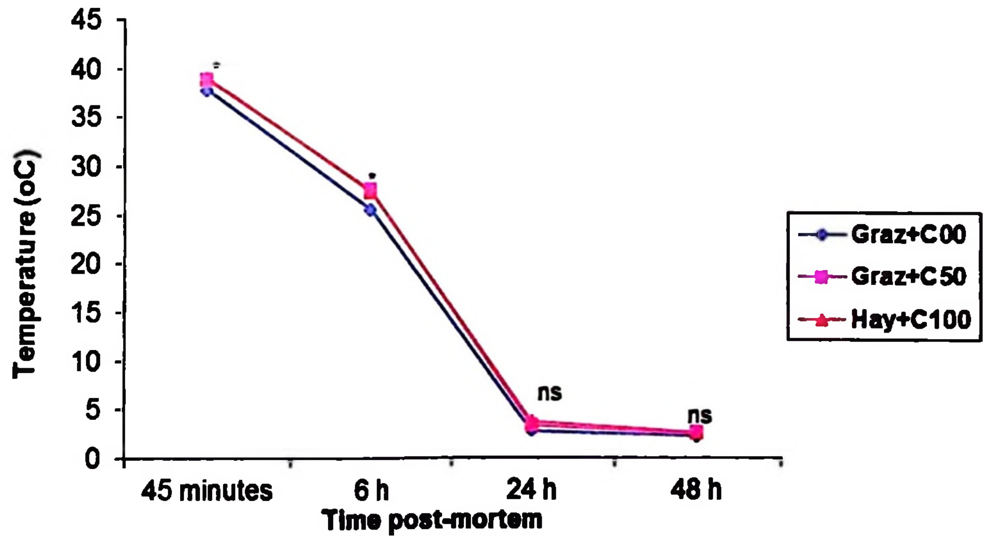


Figure 18: Effects of diet on temperature decline of Longissimus dorsi (LD) muscle from carcasses in Expt. 2

4.2.6.2 Post -mortem (pm) changes in pH on LD muscle

LSMeans of the main effects of breed and treatment on pH values of LD muscle pm are given in Figure 19 and 20 respectively. LSMeans of the treatments are shown in Appendix 30. Irrespective of breed and diet, mean pH value was highest at 45 minutes and gradually dropped, reaching an ultimate pH range 5.54 to 5.63 at 48h pm. There was no observed breed effect (P>0.05) on pH of LD muscle.

Steers fed Hay+C100 had significantly higher (P<0.05) pH values at 24 and 48 h pm compared to LD muscle from carcasses of steers on other treatments. On the other hand, steers on Graz+C50 had lower pH values in LD muscles than those on Graz+C00. The decrease in pH in LD muscle from 6 h to 24 h (pHchange2) was lower in carcasses of animals fed Hay+C100 compared to those on other dietary treatment. Interaction effect between breed and diet on pH values was not significant.

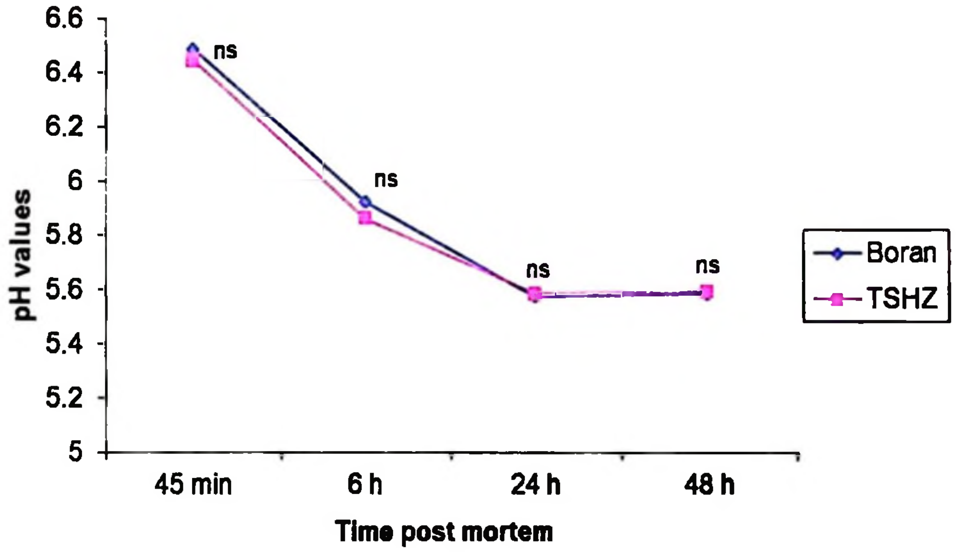


Figure 19: Effects of breed on pH changes of *Longissimus dorsi* (LD) *muscle* from carcasses in Expt. 2

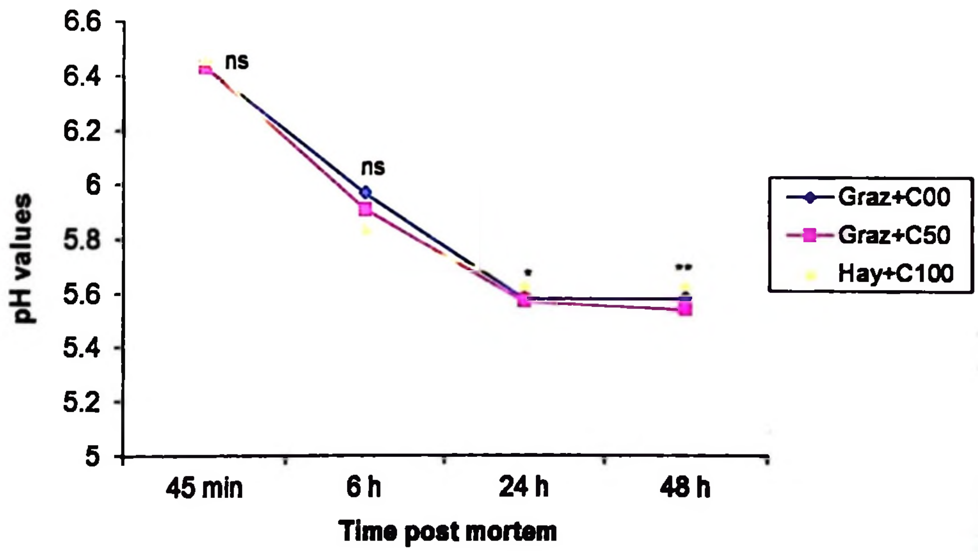


Figure 20: Effects of diet on pH changes of *Longissimus dorsi* (LD) *muscle* from carcasses in Expt. 2

The interrelationship between post-mortem temperature, pH and time in Boran and TSHZ for each diet is illustrated in Fig. 21. Temperature readings at rigor (when pH is 6) were 22.5 °C in Boran and 25 °C in TSHZ. The temperature and pH readings declined rapidly in the first 45 minutes and 6 h pm in both breeds. The pH from steers on Graz+C00 declined faster followed by Graz+C50. The fall in temperature and pH was rather slow towards 24 h and almost reached stable at 48 h pm in both breeds. Carcasses on Hay+C100 had consistently higher pH values even at 48 h pm.

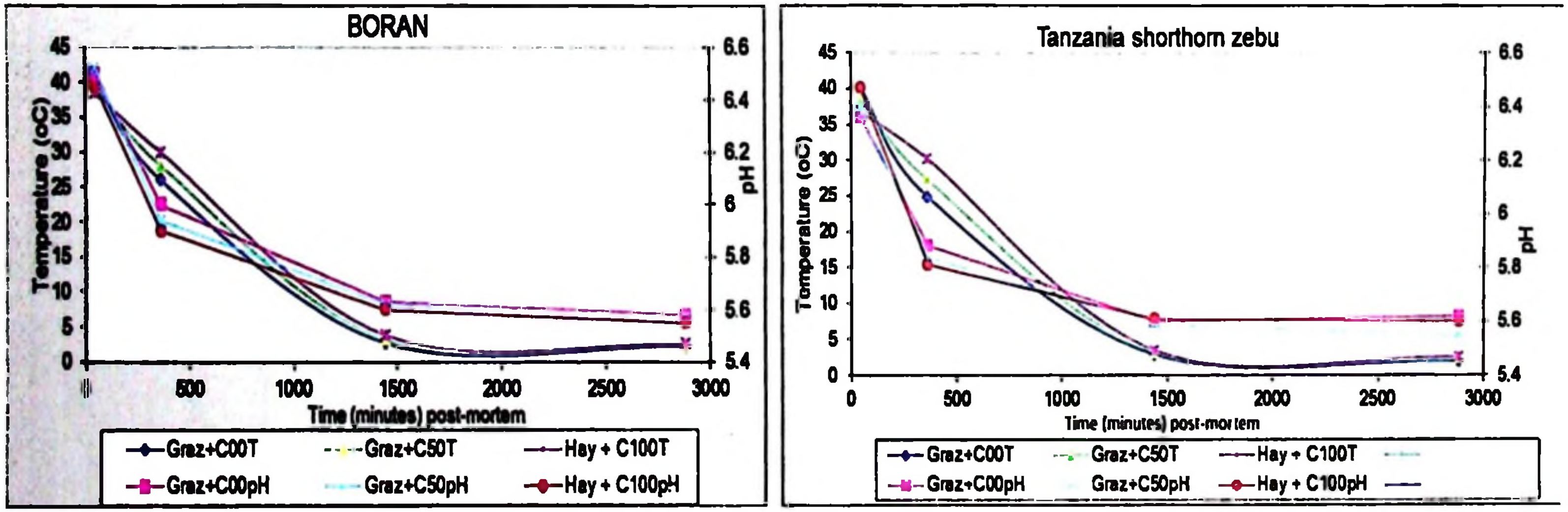


Figure 21: Post-mortem temperature decline and pH changes on LD muscle from Boran and TSHZ on different diets

4.2.6.3 The main effects of breed, diet and ageing time on meat quality attributes

Table 24 shows LSMeans of drip loss, thawing loss, cooking loss and shear force in bovine LD muscle as affected by breed and diet. LSMeans for individual treatments are shown in Appendix 31. All the measured meat quality attributes were not affected by breed. Similarly the influence of diet on drip loss and thawing loss was not significant (P>0.05) The difference in shear force of the LD muscle between carcasses of animals on Graz+C00 and those on diet Hay+C100 was 14.8 N.

The percentage thawing loss from LD muscle due to dietary treatments declined from 5.1 for animals on Graz+C00 to 4.9 for those on Hay+C100 while cooking losses in LD muscle was lowest in Hay+C100 (16.8%) and highest on Graz+C00 (24.0%) as shown in Table 24. Post-mortem ageing up to 20 days after slaughter reduced (P<0.05) thawing loss but did not affect (P>0.05) cooking loss (Table 24). Increasing storage time from 2 to 10 days pm reduced thawing loss by 37 %. There was no significant change in thawing loss observed from 10 to 20 days pm. Storage of bovine LD muscle up to 20 days pm at refrigerated temperatures (0 – 4^0C) decreased shear force (Table 25). In general, shear force decreased by 25 % from 2 -10 days ageing and by 21 % from 10 – 20 days ageing. The overall treatment effect of breed, diet and post-mortem storage time on shear force values of LD from Boran and TSHZ is illustrated in Figure 22. There was an interaction effect between ageing and dietary treatment (P>0.05) in shear force. Post-mortem storage resulted in decreased shear force of LD muscle in all animals. LSMeans of the individual effect of breed and ageing time (days) and the effects of diet and ageing time (days) on percentage thawing loss, cooking loss and shear force on muscle LD is presented on Appendix 32-33.

Table 24: LSMeans of the main effects of breed and diet on percentage drip loss, thawing loss, cooking loss and shear force on LD muscle in Expt. 2

	Meat quality attributes			
Parameter	**Drip loss (%)**	**Thawing loss (%)**	**Cooking loss (%)**	**Shear force (N)**
Breed (B)				
No of obs.	36	36	36	36
Boran	3.7	5.6	19.5	51.3
TSHZ	3.1	5.2	21.4	52.1
SEM	0.3	0.5	0.9	1.4
P-value	0.1359	0.5344	0.4164	0.6873
Dietary treatment (D)				
No of obs.	24	24	24	24
Graz+C00	3.8	6.1	24.0[a]	59.5[a]
Graz+C50	3.2	5.7	20.8[b]	50.9[b]
Hay+C100	3.1	4.9	16.8[c]	44.7[c]
SEM	0.3	0.6	1.1	1.7
P-value D	0.3397	0.3291	<.0001	<.0001
P-value B*D	0.9304	0.2812	0.2043	0.1448

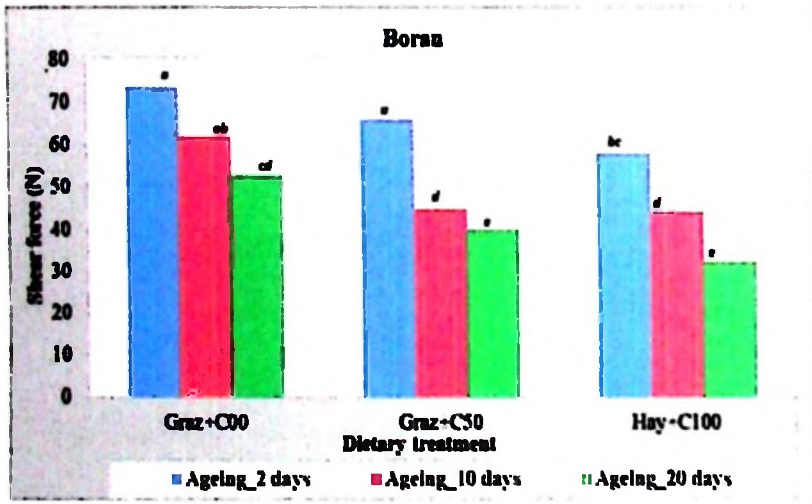
[abc]LSMeans with different superscripts in the same column are significantly different (P<0.05). Probability values (*P*-value); Standard error of mean (SEM); Graz+C00 =grazing alone as control: Graz+C50= grazing + 50 % *ad libitum* concentrate intake and Hay+C100 = *ad libitum* hay and *ad libitum* concentrate intake.

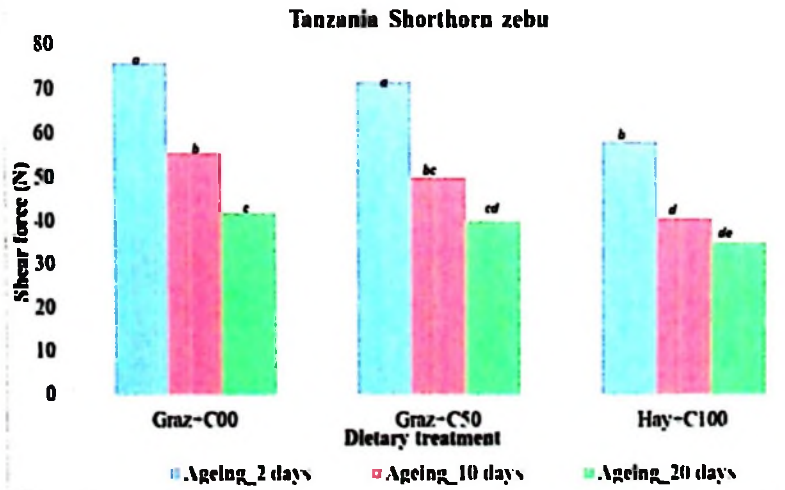
The shear force values of LD muscle from Boran and TSHZ steers on either Graz+C00 or Graz+C50 at 10 days post-mortem storage were similar to the shear force values of LD from Hay+C100 obtained on 2 days of storage (Fig. 22).

Table 25: LSMeans for the main effects of ageing time (days) on percentage thawing, cooking losses and shear force of muscle LD in Expt. 2

Parameter	Ageing time (days)				
	2	10	20	SEM	P-Value
Thawing loss (%)	7.0[a]	4.4[b]	4.7[b]	0.5	0.0005
Cooking loss (%)	19.5	21.4	20.5	1.0	0.4216
Shear force (N)	66.1[a]	49.6[b]	39.4[c]	1.5	<.0001

[abc]LSMeans with different superscripts in the same row are significantly different (P<0.05). P-value = Probability values; and Standard error of mean (SEM)





[abcde] LSMeans with different superscripts between bars chart are significantly different ($P<0.05$). Graz+C00 =grazing alone as control; Graz+C50= grazing + 50 % *ad libitum* concentrate intake and Hay+C100 = *ad libitum* hay + *ad libitum* concentrate intake.

Figure 22: LSMeans on the effects of breed, diet and ageing time on Warner-Bratzler shear force (N) on LD muscle in Boranand TSHZ in Expt. 2

4.2.7 Net returns of fattening cattle in Expt. 2

Net returns (NRs) of fattening cattle under the three treatments used in Expt. 2 are present in Table 26. The table also give NRs from purchasing cattle (i.e. none intervention), slaughtering and selling the carcass directly instead of keeping the animals for 90 days on pasture as the case in Graz+C00. This table is derived from costs of inputs used (Appendix 34), costs for individual treatment (Appendix 35), estimated unit cost of producing one kg of carcass (Appendix 36), LSMeans of the effects of breed and diet on production costs and Net returns (Appendix 37) and NRs for individual treatment (Appendix 38) using prevailing prices in the market during experimental period and hypothetical better prices case 2 and 3 which were some of the current selling prices of imported beef sold in the supermarkets. As expected the Net returns (NRs) were positive in none intervention scenario values been above 4 times in Boran compared to TSHZ. In addition, the NRs were positive for animals in Graz+C00, values also being above 4 times in Boran compared to TSHZ. The highest profit was obtained when animals were bought from auction, and sold directly in the butchers, net returns being Tshs 63,000 for Boran and Tshs 13,600 for TSHZ. Net returns were negative in all other treatments with values decreasing with increase supplementation. Boran had lower negative net returns than TSHZ in all treatments.

Table 26: Cost and Net returns (Tshs. '000) per head of fattening cattle in Expt. 2

	Dietary treatments			
	None I*	Graz+C00	Graz+C50	Hay+C100
Boran				
Cost of animals	318	318	318	318
Concentrate mix	0	0	100	217
Hay	0	0	0	28
Pasture/Grazed	0	31	31	0
Veterinary drugs and services	0	6.25	6.25	6.25
Labour (man-days)	0	8	10	41
Transportation	7	14	14	14
Total variable costs	325	377	479	624
Fixed costs	0	0	6	6
Total cost	325	377	485	631
Total Revenue	389	389	438	560
Gross margin	63	12	-41	-64
Net returns 1	63	12	-48	-71
Net returns 2	-	-	202.4	249.4
Net returns 3	-	-	390	489.4
Tanzania Shorthorn zebu				
Cost of animals	270	270	270	270
Concentrate mix	0.0	0.0	96.6	195
Hay	0.0	0.0	28.2	24.6
Pasture/Grazed	0.0	30.8	30.8	0.0
Veterinary drugs and services	0.0	6.3	6.3	6.3
Labour (man-days)	0.0	7.6	9.9	40.9
Transportation	6.9	13.9	13.9	13.9
Total variable costs	277	329	456	550
Fixed costs	0.0	0.0	6.5	6.5
Total cost	277	329	462	557
Total Revenue	291	291	361	487
Gross margin	13.6	-38.1	-95.2	-63.8
Net returns 1	13.6	-38.1	-102	-70.3
Net returns 2	-	-	132.5	207.7
Net returns 3	-	-	287	416.2

*None I = control (direct purchase and sell immediately)

CHAPTER FIVE

5.0 DISCUSSION

5.1 Nutritive Values of the Feedstuffs Used in the Study

The quantity and nutritive values of pastures grazed

The observed higher yields of forage species during the wet season (Tables 11) relative to dry season (Tables 19) have implication on the nutrient availability and hence performance of the grazing animals during the two seasons. The observed low forage mass which decreased further as the dry season progressed was in agreement with studies by Bwire *et al.* (2003) and De Leeuw *et al.* (1999) who reported that forage quality and quantity are affected by season and is a major constraint to increased cattle productivity under most tropical livestock farming conditions. The dominance of *Aristida adscensionis* in the paddocks grazed represents a typical situation in most semi-arid areas where there is a continuous pressure of grazing. In such areas annual species dominate and replace the nutritious and palatable perennial forage species, such as *Cenchrus ciliaris* (Butterworth, 1985; Mero and Udén, 1998). The observed values of frequency occurrence of herbaceous legumes in the present study (Appendix 5 and 24) agree with findings reported by Herlocker (1999) and that *Macrotyloma uniflorum* could be an annual or perennial herb in grazing lands in many areas of tropical Africa. The dominance of annual species in the grazing area ensures availability of quality forage to grazing animals especially during the wet season.

Considering the fact that Experiment (Expt.) 1 coincided with the beginning of wet season (precipitation) and Expt. 2 was conducted at the start of the dry season, the quality of the grazed forages was expected to be different (Butterworth, 1985). The forage DM contents in Expt. 1 decreased (from 560 to 359 g/kg fresh forage) whereas those in Expt. 2 increased (from 662 to 867 g/kg fresh forage) with progressing experimental periods. The observed crude protein (CP) values of the forages in the two experiments could be compared diagrammatically as shown in Fig 23.

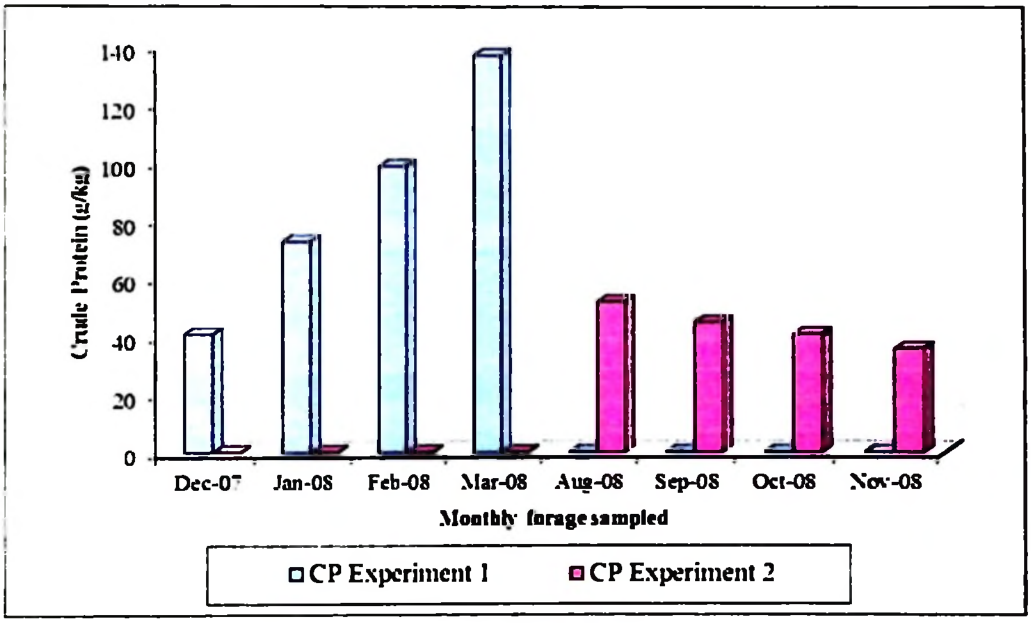


Figure 23: Mean values of crude protein content (g/kg) of forage samples from grazed paddocks in Expts. 1 and 2

The CP values increased from the start of the experiment until the time when steers were taken for slaughter (March, 2008). The observed increase in crude protein content of grazed pastures with progression of wet season (December to March) was in agreement with other studies (Mwilawa, 1996; Bwire *et al.*, 2003; Mtengeti *et al.*, 2006) that tropical forages are high in nutritive value during wet season. On the other hand CP values of forages grazed in Expt. 2 decreased from the start until the animals reached slaughter time (December, 2008). The trend in changes in nutritive value with season is in agreement with earlier studies (Mtengeti *et al.*, 2006) which reported on the tendency for CP to decrease and cell wall content to increase with advancement of dry season and this is associated with the observed low *in vitro* organic matter digestibility (IVDOM) due to increased lignifications of NDF fraction.

The obtained mean CP value (87 g/kg DM) of grazed forages in Expt. 1 was above the recommended minimum value (70 g CP/kg DM) for maintenance requirement for grazing animals (Ekaya, 1991), whereas value (43 g CP/kg DM) for Expt. 2 were lower than the recommended minimum value (Butterworth, 1985; De Leeuw *et al.*, 1999). In such situation grazing animals in Expt. 1 where animals had opportunity to select it is likely that high nutritious pasture were available to animals while in Expt. 2 forages were of low quantity and of less nutritive value. Therefore, under such situation animals need to be supplemented. The higher values of *in vitro* digestible organic matter (IVDOM) and hence ME contents observed in the grazed forages during the wet than dry seasons implicates that grazed animals in Expt. 1 is expected to have higher performance than those in Expt. 2.

The nutritive value of concentrate mixture used

There was a similarity in the nutritive values of concentrate feeds used by steers under feedlot during Expts. 1 and 2. The CP content (135 g/kg DM) of the formulated diet was within the acceptable range of 120 to 140 g/kg recommended by Topps and Oliver (1993) for fattening cattle. The ME content (13.2 MJ/ kg DM) was similarly within the recommended range (12.5 to 13.6 MJ ME/kg DM) under East and Central Africa conditions (Topps and Oliver, 1993). The values of protein and energy are also within the values used by Creek (1972) working with fattening Boran in Kenya, Jepsen and

Creek (1996) working with Boran cattle in Ethiopia and Norris *et al.* (2002) working with Tswana cattle in Botswana.

5.2 Feed Intake and Growth Performance

The recorded dry matter intakes (DMI) of the stall fed animals under feedlot ranged from 3.1 to 3.3 per cent of body weight in Expt. 1 and 3.1 for Expt. 2 and these values were within the range of 2.7 to 3.5 percent observed by Topps and Oliver (1993) for fattened beef cattle fed concentrate at *ad libitum* intake. The observed higher hay DM intake as % of LW by steers on Hay+C60 relative to those on Hay+C80 and Hay+C100 could be due to restricted concentrate offer that forced them to take more hay, which was of lower energy concentration. This observed inverse relationship between intake and diet energy concentration suggested that as the level of dietary energy concentration increases, there is a tendency of the animal to adjust intake so that they can meet their physiological energy requirement.Similar observation have been reported by other workers elsewhere (Knoblich *et al.*, 1997; Meissner *et al.*, 1995; Hennessy *et al.*, 2001; Huhtanen *et al.*, 2006).

The higher average daily gain (ADG) for Boran than TSHZ in Expt. 1 could be partially attributed to breed differences in their growth impetus. The higher initial body weights of Boran compared to TSHZ in both experiments was expected to have influence on the growth performance and carcass measurements of those animals. It is documented that Boran has higher mature body weight than TSHZ and this could partly account for superiority of the Boran (Mwatawala and Kifaro, 2001; Msanga and Bee, 2006). It is also possible that the two breeds could respond differently for the fattening diets and therefore it would have been of interest if the comparison were carried out using the two breeds at the same physiological state of development. The derived physiological ages of Boran and TSHZ at the onset of the experiment ranged from 28 to 38% and 36 to 65%, respectively of their estimated mature body weights. This implies that the two breeds were at different stages of growth and hence the differences in their growth performance (Berg and Butterfield, 1976; Lawrence and Fowler, 1997).

The observed average daily gain (ADG, 854 g/day) of Boran breed under feedlot condition (Hay+C100) in Expt. 1 compare well with findings by Jepsen and Creek (1976) who observed a gain of 883 g/day. However lower mean value (769 g/day) was obtained in Expt. 2. The ADG for TSHZ under similar feedlot condition recorded comparable mean values (812 and 702 g/day) in Expts.1 and 2 respectively. The lower gain of animals in Expt. 2 relative to Experiment 1 could possibly be due to the differences in age, whereby animals in Expt. 2 were older than those in Expt. 1, thus they were at different stage of growth.

The responses in ADG due to dietary treatments in the current study were similar in both breeds, being highest on Hay+C100 for both Expts. 1 and 2, and lowest on Hay+C60 for Expt. 1 and Graz+C00 for Expt. 2. The trend was similar in each respective diet in Boran and TSHZ indicating that both breeds could be used for fattening. Similar findings were reported by Strydom *et al.* (2008) who observed that steers from the herds of emerging and communal farmers showed similar growth performance. The higher ADG in *ad libitum* concentrate intakes was expected. This could have been attributed by sufficient energy and nutrients concentration in the concentrate diet to support body weight gain (Weisbjerg *et al.*, 2007; Andersen *et al.*, 2005; Norris *et al.*, 2002). Similar observations were reported by Roberts *et al.* (2009) that increasing the amount of grain in the diet of finishing cattle resulted in a linear decrease ($P<0.05$) in days in feed intake and a linear increase ($P < 0.05$) in ADG. The findings from the present study were also within the range reported by Slabbert *et al.* (1992) of 600 – 1480 g/day in South Africa and those of Norris *et al.* (2002) in Botswana (840 – 1220 g/day). However, they were slightly lower to those reported by Luziga (2005) of 1130 g/day with Boran X Ayshire steers using molasses based diets.

The observed relatively better growth performance of animals on Graz+C00 and Graz+C50 than those on Hay+C60 during Expt. 1 could be attributed by the high quantity and quality of forages available in the grazing paddocks relative to the poor quality hay, which formed 35 % of DMI for Hay+C60. The relative high ME and CP values observed in the forages were relatively satisfactory to provide adequate nutrients for maintenance and production (Norris *et al.*, (2002). The obtained better performance of steers under Graz+C50 and Graz+C00 relative to supplemented diets suggest that beef fattening could be possible using limited amount of concentrate when quality pasture are available. On the other hand the grazing animals in Expt. 2 performed poorly because of inadequate quantity and quality pasture. This was expected and could be attributed to the lower quantity and quality of pastures during the dry season making the animals not able to obtain sufficient nutrients required for maintenance and production. The results on animal performance suggest that stall feeding of high energy concentrate and hay is necessary for finishing animals during the dry season.

The observed overall higher (P<0.05) feed conversion ratio for Boran than TSHZ in Expt. 1 implies that the TSHZ breed is more efficient in utilizing feeds than the Boran breed. This effect could be due to the relatively lower initial body weight of TSHZ relative to Boran as explained earlier on. Consequently, protein meal supplementation should improve grazing efficiency of steers on low quality pastures through reduced energy expenditure and without compromising their digestible organic matter intake. Plant attributes such as low protein content result in reduced intake and gut fill, where nitrogen deficiency would be a factor affecting intake (Meissner et al., 1995). It is also suggested that the level of reticulo-rumen fill was influenced by other presumably protein nutrition of the animal. Animal performance is mainly depended on the intake of digestible and metabolizable nutrients which might have been limiting in grazing animals in Expt. 2, which was demonstrated by Huhtanen et al. (2006). The performance of animals during wet season could have been due to the influence of digestibility on nutrient supply indirectly due to the existing association between digestibility and intake of ruminal fed forage-based diets. The animals with high propensity to fattening, require much higher energy per unit fat than protein retention in young animals. The increase in feed conversion efficiency (P<0.05) with increasing concentrate intake suggest that as energy concentration of feeds increases, animals utilise the feeds more efficiently and this has been similarly reflected by the energy efficiency. Concentrate feeding favours propionic acid production in the rumen which is utilized more efficiently for growth and fattening. Similar trends have been reported elsewhere (Andersen *et al.*, 2005a; Abdullah and Musallam, 2007).

From the observed similar responses of the two breeds in terms of ADG and better FCR in TSHZ with increased concentrate intake suggest that both breeds can be used for feedlot production in Tanzania. The observed better ADG and FCR of grazing and supplemented animals (Graz+C50) than those fed concentrate at 60% plus hay (Hay+C60) in Expt. 1 suggest that in wet season animals could be finished on pasture plus 50 percent of *ad libitum* concentrate intake. However, during the dry season, when availability of pastures in terms of quality and quantity is limited, animals are better finished on *ad libitum* concentrate intake under feedlot practice as reflected by the better performance of animals on Hay+C100 in Expt. 2.

5.3 Killing Out and Carcass Characteristics

The observed higher Final liveweight (FLW) from Boran than TSHZ in both experiments was expected due to the differences in their initial bodyweights. The higher starting weight of the Boran steers was reflected in higher empty body weight, hot carcass weight (HCW), dressing percentages and non carcass components than TSHZ. The observed trends of the FLW and HCW with respect to dietary treatments reflect the recorded high ADG. The low dressing percentages in TSHZ were due to higher proportion of gut content. Several studies have reported larger gut fill in Fresian and their crossbreds especially when they are raised on poor quality roughages. The argument for this has been an adaptation to compensate for the low quality feeds i.e. to have more gut fill to extract more nutrients. On the other hand it could be due to their slow rate of rumen evacuation rate of passage of rumen contents. Similar results were reported for Nguni breed in Southern African countries (Strydom *et al.*, 2008).

There is also enough evidence of close positive association between live weight and DP (Casasús *et al.*, 2002; Skunnum *et al.*, 2002) and this could be reflected in the observed higher body weight hence higher DP of Boran relative to TSHZ in Expt 1. The observed low values of DP for grazing TSHZ and Boran was in agreement with available data in the literature of 47 to 50 % for TSHZ and 49 to 52 % for Boran (Mpiri, 1994; Mwatawala *et al.*, 2001; MAFS, 2003) and these could be explained by the observed higher gut fill for the grazed than concentrate fed animals in both experiments. The higher gut fill could be due to limited nutrient concentration in the feedstuff and as such animals tended to compensate by taking more of the forage so as to extract enough nutrients. A study by Jones *et al.* (1984) found that cattle on a high roughage diet, such as hay, silage or pasture, have a lower dressing percentage than cattle on a high proportion of grain diet. The reason for this could be due to more reduction in weight of the the dressed carcass relative to final slaughter weight i.e. there is more rumen fill in grazed animals than concentrate fed animals.

The observed higher dressing percentage in steers on Hay+C100 in both Expts. 1 and 2, are in agreement with the observations made by Meissner *et al.* (1995) and Hanekom, (2010) that dressing percentage and hence carcass weight increased with increase in dietary energy concentration. The reason for this increased DP with increase of amount of concentrate on offer could be attributed to several factors. Animals consume less DM that is more digestible resulting into lower gut fill as is similarly observed by Robelin and Geay (1984). Gut fill value must however be taken with caution since it can also be influenced by the quantity of water drunk, the time since cattle last ate or drank, and the rate of passage of the gut contents as reported by MRNL, (1985) in cattle and Suliman and Babiker (2007) and Mushi *et al.* (2009) in sheep. In the present study variations brought by these factors and their influence on DP were minimized by starving and withholding water for the animals for about 15 hrs before slaughter. In support of the present findings, other studies have compared steers on grains (fast gaining) or on roughage (slow gaining) and found that dressing percentages averaged 2 per cent higher for the steers on fast than slow gaining rations (Falmey, 1986).

The values for carcass measurements observed in the present study were lower than the reported values for TSHZ and their crosses (Mpiri, 1994) and Iringa red zebu (Nalaila, 2005). Animals used in both studies were slaughtered with age more than 4 years, whereas in the present study the animals slaughtered were less than 3 and 4 years for Boran and TSHZ respectively. This could account for the observed differences between the present findings and those of earlier studies. The body measurements increased with increasing concentrate intake reflecting the superiority in growth rate and hence hot carcass weight. These results are in agreement with the findings by McGee *et al.* (2007) who observed significantly greater body measurements for animals on intensive system than those on extensive system, and attributed it to differences in live weight and hence carcass weight brought by the feeding systems.

High levels of concentrate intake gave the highest scores in carcass conformation and fatness level, relative to grazed animals and this was attributed to the variation in energy intake. The significance of carcass conformation scores in meat industry lies on the price attached to the carcass. Carcass with high scores have better market price. Also the slopes of carcass conformation are related to intramuscular fat (marbling) which is preferred improving tenderness as reported by Sañudo *et al.* (2009). Furthermore, as in proportions of lean and fat in dietary treatments. Fat being a late maturing tissue have growth coefficient greater than one as documented by Hammond *et al.* (1971) and Berg and Butterfield (1976) and it is easily malleable by nutrition and other factors. The results showed increase in amount of fat with increase in concentrate intake. Bone is an early maturing tissue and the possibility of affecting its growth through nutrition manipulation is minimal (Berg and Butterfield, 1976; Kerth *et al.*, 2007; Atti *et al.*, 2004). The lower ratio of lean:fat for Boran than TSHZ and animals in high concentrate than low concentrate intake was attributed to the higher proportion of fat in those carcasses. Warris (2004) reported similar findings in sheep and cattle that with increased proportions of fat lead to a decreased proportion of lean in the carcass during the finishing period.

It is concluded from this section that Boran and TSHZ breeds can be used for feedlot production but Boran is likely a suitable candidate as measured by ADG, DP and meat quantities, It is also concluded that it is possible to use limited amount of concentrate in beef fattening when quality pastures are available. Where pasture is of very low quality as was the case in the dry season, it is suggested that a complete feedlot practice be used using high energy concentrate and hay in finishing animals.

5.4 Meat Quality Characteristics

5.4.1 Temperature decline post-mortem

In the two studies the rate of temperature fall was slower in carcasses in Expt. 2 probably because the animals used in Expt. 2 were rather older and heavier and had thicker fat layer carcass compared to animals in Expt. 1 The higher temperature decline (Tdrop1) in Boran than TSHZ in Expt. 1 was unexpected because carcasses from Boran were heavier and had more fat thickness than those of TSHZ, thus they were expected to lose heat at a slower rate. Sinclair *et al.* (2001) and Bowling *et al.* (1978) found that carcasses which are heavier with thick surface fat layer took longer to cool. Similar decline in temperature (Tdrop1) of carcasses from Boran and those from TSHZ in Expt. 2 match well with the similarity in their fatness. The decrease ($P<0.05$) in heat loss (Tdrop1) from the carcasses with increased concentrate intake could mainly be due to relatively high subcutaneous fat and weight of the carcasses from those animals. Subcutaneous fat normally act as an insulator to the inner tissues, thus preventing heat transfer to the cool environment.

5.4.2 pH changes post-mortem

The observed high pH values at 45 minutes after slaughter and the decline to pH range (5.58 - 5.59) at 24 h pm could be due to slow cooling as shown by values of Tdrop 1 implying that the handling of animal's prior to slaughter was not stressful (MLA, 2002). Since the pH reading reached 6 while the temperature was still high (>26^0 C) indicates that there was no cold shortening (MLA, 2002; Purslow, 2002). The ultimate pH reached was within the acceptable range (5.4 to 5.8) reported by Pratiwi *et al.* (2007) and Bruas-Reignier and Brun-Bellet (1996).

The lack of differences in pH values between Boran and TSHZ in the present study is in agreement with the observations made by Frylinck *et al.* (2006) on the indigenous Sanga zebu cattle genotypes and Monsóon, *et al.* (2004) on European cattle (Holstein, Old Brown Swiss, Limousin and Blonde d'Aquitaine). This could imply that the biochemical reactions taking place in the muscles are not different between breeds. The observed higher ($P<0.05$) pH values with grazing animals at 6 h pm in Expt. 1 could be associated with differences in oxidative capacity and glycolytic processes. The grazing animals probably had less glycogen in their muscles leading to lower lactic acid formation than those fed on concentrate. However, this trend was not clearly shown in Expt. 2.

5.4.3 Drip loss

The average values of drip loss obtained in both Expts. 1 (4.0 %) and 2 (3.4 %) were within the normal range (1-5 %) in beef as reported by Purslow (2002) and Jama *et al.* (2007). The observed none significant difference (P>0.05) in drip loss between breeds means that the oxidative processes were the same. In both cases cell membrane integrity were stabilized post-mortem, sarcoplasm was retained in muscle cells and thereby resulted in less and more weight retention during storage. The observed results were similar to findings by Jama *et al.* (2007) using Nguni, Bonsmara and Angus cattle at the same ageing (2 and 21) days. However, breed differences in drip loss were reported by Frylinck *et al.* (2006) among Sanga cattle and Brugiapaglia *et al.* (2008) between Friesians and their crosses where pure Friesians had higher drip losses in comparison with Friesian crossbreds (3.62 vs. 3.08 %; P<0.05).

The relatively high drip loss values for grazing animals could be due to the lower fat and higher lean contents observed in the carcasses of the grazing animals than those fed concentrate. High fat content in the carcass means less water content and higher water holding capacity attributed to the fat layer that prevents passage of water from the tissues (Dawson *et al.*, 2002). The result obtained in this study of 3.5 and 3.1 % for Hay + C100 in Expt. 1 and 2 respectively is recommendable and could be attributed by increased

ADG and amount of fat. Elsewhere, low drip loss has shown to be reduced by 3% in cattle fed diets containing high amount of maize grain (Brugiapaglia *et al.*, 2008).

5.4.4 Thawing loss

The values obtained on thawing loss were within the range for beef (4-6%) as reported by Jeremiah and Gibson (2003). The lack of breed difference in thawing loss from the LD muscle in the present study concurs with the findings reported by Jama *et al.* (2007) when comparing Nguni (3.26 %), Bonsmara (3.35 %) and Angus (3.60 %). The higher values of thawing loss from the LD muscle for grazing animals than those fed concentrate in both experiments could possibly be related to water holding capacity attributed to fat content in the carcass (Andersen *et al.*, 2005b; Sañudo *et al.*, 1998), where concentrate fed animals had higher fat content than grazing animals. The fat content in the carcass insulates the muscle proteins to denature easily as the pH falls.When muscle proteins denature it leads to reduction in their power to bind water. Also the myofibrillar proteins, myosin and actin, reach their isoelectric point where loses water which is normally bound in the muscle.

5.4.5 Cooking loss

On average cooking loss decreased with increase in concentrate intake. As the meat is cooked, proteins are denatured and water with mineral and vitamins is lost. Carcasses from supplemented concentrate diets had more intramascular fat that reduced denaturation process of proteins and hence less losses. The mean cooking loss (20.5%) of LD muscle observed in Expt. 2 was lower than the value (22.5%) reported by Jeremiah and Gibson (2003) and values (24% and 25.8%) reported by Jama *et al.* (2007).

However, mean value (24.9 %) obtained in Expt. 1 was higher than Expt. 2 and those of Jeremiah and Gibson (2003), but comparable to those reported by Jama *et al.* (2007). Razminowicz *et al.* (2006), however, obtained considerable high value (30 %) in pasture-fed (or grazing) steers.

The differences in cooking losses in the current study and those reported by other authors may be attributed to several factors, such as the differences in meat ageing time, cooking methods, pH and level of marbling in the carcass (Yu *et al.*, 2005). Ageing of meat decreased losses in Expt 1. This was due to the weakening of myofibrils with but increased ageing days. Similarly it is likely that the attachment of the thin (actin) filaments to the Z discs which breaks and losses more water soluble nitrogen compounds. During pH fall more proteins tend to denature which leads to loss of waterholding capacity and protein solubility. Marbling could have also influenced losses since on cooking fat usually melts and hence could be lost.

The observed cooking losses are associated with endogenous enzymatic reactions such as collagenase, which is produced by bacteria within beef or ionic solubilisation, which releases water with nutrients on cooking. Cooking loss has a large financial implication in beef industry because it results in the loss of several essential minerals and vitamins resulting in the deterioration of nutritive quality of beef. The obtained results (low values) on cooking loss have positive financial implication to beef industry in Tanzania. The higher ($P<0.05$) mean value of cooking loss from LD muscle from TSHZ than Boran in Expt. 1 could possibly be due to fat content in their carcasses which melts in the process of cooking. Similar observation was made by Jama *et al.* (2007) who found breed differences (P<0.05) in cooking loss when comparing Nguni, Bonsmara and Angus beef cattle. However, in Expt. 2 breed difference (P>0.05) in cooking loss of LD muscle was not significant, a finding which was in agreement to observation made by Mitsumoto *et al.* (1995) and Brugiapaglia *et al.* (2008). This discrepancy could be attributed to differences in slaughter age of those animals. The decreased cooking loss with increased level of concentrate intake in both experiments is attributed to the increased level of marbling in the carcasses (Yu *et al.*, 2005). Although there was no difference (P>0.05) in cooking loss between ageing periods, the tendency was for the losses to decrease with increased ageing time, similar to what was reported by Jama *et al.* (2007).

5.4.5 Effect of breed, diet and ageing on meat tenderness

The readings of Warner-Bratzler shear force (WBSF) recorded from 2 to 20 days ageing times ranged from 62.9 to 37.3 N in Expt. 1 and 66.1 to 39.4 N in Expt. 2, that means s at 2 days ageing the values were higher than those reported by Shackelford *et al.* (1997). The authors (Shackelford *et al.*, 1997) classified meat as tender when the WBSF values were less than 58 N at 2 days of ageing. This suggests that the meat from animals in the present study (Boran and TSHZ) can be considered as been tough when sold warm as is been practiced in abattoirs in Tanzania. Due to the fact that at 10 days of ageing meat from the two breeds had attained a shear force of 48.7 and 49.6 N in Expt. 1 and 2 respectively, it means the meat was already tender even before the 10 days ageing. Probably the meat became tender to acceptable level somewhere between 2 to 10 days and therefore need further investigation.

The lower shear force values on LD muscle of Boran than TSHZ could have been due to differences in the distribution of various tissues in the muscle of the two breeds. Although not assessed in the present study, high amount and concentration of connective tissue in muscles normally increases shear force values as discussed by other workers (Andersen *et al.*, 2005; Santos-Silva *et al.*, 2002; Dawson *et al.*, 2002; Mushi *et al.*, 2007). It must also be mentioned that TSHZ was physiologically older and hence this could also have accounted for the higher shear force values. Breed differences in shear force have been documented in detail by Koch *et al.* (1982) and McKeith *et al.* (1985) who reported higher shear force values for *Bos indicus* than *Bos Taurus*, implying that *Bos indicus* produce tougher meat. Koch *et al.* (1982) further noted that meat from cattle possessing *Bos indicus* blood has higher shear force than that from cattle possessing *Bos taurus* blood. Other workers (Shackeforld *et al.*, 1997; Crouse *et al.*, 1989) showed a positive relationship between breed and shear force.

The decreased shear force values with increased concentrate intake in both experiments in the present study signify that meat tenderness improves with concentrate feeding. The possible reason for low shear force values with concentrate feeding where *ad libitum* concentrate intake had the lowest value (41.8 N) is that high energy diets usually give rise to higher *in vivo* protein turn over (Andersen *et al.*, 2005a) and lower concentration of connective tissues per unit muscle weight bundle which are associated with meat tenderness (Maltin *et al.*, 2003; Lefaucheur *et al.* 2002; Sinclair *et al.*, 2001). In addition, animals on concentrate supplementation deposited more fat in muscle bundles, thus lowering the concentration of connective tissues and hence shear force values in cattle (Christensen *et al.*, 2007, Lawrie and Ledward, 2006; Maltin *et al.*, 2003) and in lambs

(Kristensen *et al.*, 2002; Mushi *et al.*, 2007). Diets with low energy such as grass or forage give rise to muscles with higher shear force values when compared to high energy diets fed *ad libitum* (Andersen *et al.*, 2005a).

The significant decrease in shear force in LD muscle observed from 2 to 20 days indicates that proteolysis was still taking place after prolonged storage post-mortem in both Boran and TSHZ as suggested by Sentandreu *et al.* (2002) and Jayasooriya *et al.* (2007). Proteolysis of myofibrillar proteins presumably played a major role in postmortem meat tenderization. It is likely that Ca2+dependent proteases (CDP) and certain cathepsins might have degraded myofibrillar proteins. Either CDP, cathepsins or their synergistic action could be the primarily responsible for post-mortem changes leading to meat tenderization as argued by other workers (Asghar and Bhatti, 1987; Koohmaraie, 1996). Also there were differences in the rate of post-mortem meat tenderization among breeds. The structural changes occurring in skeletal muscle during post-mortem storage of carcasses at refrigerated temperature that lead to meat tenderization could be due to the proteolytic action of endogenous proteases cathepsins are capable of hydrolysing myofibrillar proteins. The action of one or more of these classes of proteases presumably could be responsible for post-mortem changes in skeletal muscle. In the present study shear force decreased by 23% from 10 to 20 days which was similar to the rate reported by Purchas *et al.* (1999) in muscles from steers and bulls of similar age (20 -22 months).

Ageing tended to decrease shear force values of LD muscle in both breeds, although the rate was higher in TSHZ than Boran. A similar observation was reported by Strydom *et al.* (2008) who found that shear force of loin muscle from improved Bonsmara zebu and

(Kristensen *et al.*, 2002; Mushi *et al.*, 2007). Diets with low energy such as grass or forage give rise to muscles with higher shear force values when compared to high energy diets fed *ad libitum* (Andersen *et al.*, 2005a).

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Ageing tended to decrease shear force values of LD muscle in both breeds, although the rate was higher in TSHZ than Boran. A similar observation was reported by Strydom *et al.* (2008) who found that shear force of loin muscle from improved Bonsmara zebu and their crossbreds tended to decrease faster from slaughter to 2 days post-mortem than those of Brahman. The observed significant interaction between diet and ageing time concurs with the findings by Strydom *et al.* (2008) who reported that both breed and feeding strategy had significant influence on the effect of ageing on shear force value. This trend could be due to many factors which act singly or in combination, such as post mortem proteolysis, absence of cold shortening, amount of intramuscular/ subcutaneous fat and rate of pH and temperature drop during rigor development (Taylor, 2003, Hopkins *et al.*, 2002; Koohmaraie *et al.*, 2002; Sentandreu *et al.*, 2002, Dransfield, 1994; Koohmaraie, 1994). Natural enzymes act to break specific muscle protein strands into smaller pieces to result in improved LD muscle tenderness. Most tenderization occurred early in the post-mortem ageing process, and by 10 days post-mortem, most tenderization had occurred. Although post-mortem ageing has a profound optimizing effect on LD tenderness, other ante- and post-mortem factors could impact tenderness.

In both Experiments 1 and 2, cold shortening was probably prevented since the temperature did not fall below 10°C until when the muscle pH reached 6.1 prior to taking the carcasses into cold room. In this way the effect of ageing on shear force of muscle was enhanced (Koohmarie, 1994; Koohmaraie *et al.*, 2002). In addition, Jayasooriya *et al.* (2007), Bruas-Reignier and Brun-Bellut (1996), Ouali (1990) noted that post-mortem changes with ageing in muscle tissue vary strongly between individuals in different diets and these changes can occur up to 42 days depending on storage conditions. However, the ultimate shear force at 20 days chosen in the present study was due to the fact that beyond 21 days the fall in shear force is small (Goll *et al.*, 2003) and may not justify the extra cost of storage.

It will therefore be beneficial in improving tenderness by ageing the carcass between 2 to 10 days as was observed in this study however the exact duration would be determined by the cost of utilities, such as electricity and space. The willingness of customers in paying for much tender meat would also determine the length of ageing.

From the results of the two experiments, both Boran and TSHZ gave acceptable range of values of meat quality particularly on drip loss, thawing loss and cooking loss. Both breeds when supplemented could give tender meat that required minimum days in storage rooms. It is possible, therefore to manipulate shear force values and hence tenderness of meat from Boran and TSHZ through concentrate feeding and storage at room temperature for 10 h post-mortem followed by chilling at 0 - 4^{0}C from 10 to 20 days.

5.5 Profitability of Fattening

In both experiments (Expts.) 1 and 2 when the prevailing price of meat was used, positive returns were obtained from animals in non intervention and in Graz+C00 whereas all other dietary treatment gave negative returns. The higher net returns from non-intervention animals could be due to minimum input used which was mainly transport. This is in agreement with earlier reviewers who reported that feed costs are cheaper in grazing cattle (Madsen *et al.*, 2004; Weisbjerg *et al.*, 2007). However, the value of beef from grass-finished cattle is often discounted compared with concentrate-fed beef because of perceived differences in tenderness; colour, juiciness and flavour (French *et al.*, 2001; Kristensen *et al.*, 2002). Concentrate-fed animals produce more tender and better flavoured meat than forage-fed animals and thus should fetch higher price per kg (Santos-Silva *et al.*, 2002; O'Sullivan *et al.*, 2004).

The major costs associated with feed-lotting in this study were mainly cattle and feeds and this accounted for 86 % of the cost in both Expts. 1 and 2 of the feedlot enterprise, a value which is slightly lower than 92% of the total costs reported by Malope *et al.* (2007) in Botswana. Feed costs alone contributed about 39 % of the total variable costs a value which is slightly similar to 37% of the total variable costs reported by Malope *et al* (2007). However, when the costs of cattle are excluded in the present study, feed costs alone account for 78% of the remaining variable costs, a value which is within the range reported by other workers of 70 – 80 % (Henning, 1999; Skunnum *et al.*, 2002). As expected feed costs were the major variable costs observed in both Expt. 1 and 2. Dietary treatment with *ad libitum* concentrate intake had highest total costs among the treatment. This is due to the feeds compositions used that aimed to provide the necessary energy and protein required to attain faster growth rates during feedlot period, a characteristics of finishing feeds recommended by various authors for finishing cattle (Norris *et al.*, 2002; Weisbjerg *et al.*,2007).

In order to have a meaningful profitability analysis one was to carryout the break-even analysis for the level of output/minimum herd size, selling price and purchase price, weight gain and cost of gain. In this study the analysis was limited to the selling market price during the experiments and assumed hypothetical selling prices. Considering the value of the product due to feedlot intervention (Graz+C50, Hay+C60, Hay+C80 and Hay+C100), three scenarios were considered in assuming the selling price of the product, where the market would be willing to pay more for the quality produce (case 2 Tshs 3,500/=, or case 3 Tshs. 5,500/=, or case 4 Tshs 7,000/= per kilogram of carcass). It was apparent that in both Expts. 1 and 2 significant Net returns were realized when the

CHAPTER SIX

6.0 CONCLUSION, RECOMMENDATIONS AND AREAS FOR FURTHER RESEARCH

6.1 Conclusions

From the results of the study on effects of different diets on weight gain, carcass and meat quality characteristics of two breeds of cattle conducted in central part of Tanzania in the wet and dry seasons, it can be concluded that:

i. Boran and TSHZ can be used for feedlot production in Tanzania as both breeds had similar trend in responses in terms of growth rate, feed conversion ratio, dressing percentage, carcass composition and other quality meat attributes with increased concentrate intake.

ii. Boran cattle were superior candidate for fattening enterprises as judged by average daily gain, final Liveweight, dressing percentage, carcass measurements and carcass conformation score, values been higher for Boran than TSHZ.

iii. Limited amount of concentrate on supplementation can be used in finishing cattle when quality pastures are available in the wet season. On the other hand, *ad libitum* energy rich concentrate (a complete feedlot practice) with hay acting as buffer is necessary for finishing animals during the dry season because of low quantity and quality of both pasture and hay.

iv. Acceptable tender meat can be produced from indigenous Boran and TSHZ cattle under feedlot by ageing carcasses to nearly 10 days; the length of ageing depends on the diet, been shortest for carcasses from animals on *ad libitum* concentrate intake. Furthermore, *ad libitum* concentrate intake minimized losses due to dripping, thawing and cooking.

v. Net returns from feedloting could be positive only when the final consumers were willing to pay more than the normal market price for the tender quality beef. In such situations, *ad libitum* concentrate intake could give the highest net returns at the time of the study.

6.2 Recommendations

Several issues developed during the course of this study which critically need further research and are pointed in Section 6.3.Other issues are general in nature and can be resolved by simple interventions. The general recommendations were:

i. This study clearly demonstrates that it is more expensive to produce tender quality meat compared to normal meat. The promotion of feedlot entrepreneurs will only materialize if clear net returns are demonstrated from such enterprises. This means selling the meat at higher price and in this study it was 5,500 Tshs. This has wider implications for sustainable feedlotting as it must clearly show how the wide range of stakeholders (the pastoralists, the cattle traders, people in feedlot, the butchers, supermarkets) could benefit from such enterprises. It is recommended that:

   a. In order to increase the quality and quantity of meat it is worthy to fatten the animals using *ad libitum* concentrates diets (Hay+C100) and when pastures are of good quality animals can only be supplemented with concentrate (Graz+C50).

   b. Both market and value chain analyses of producing quality meat be carried out.

c. Economic analysis involving market surveys need to be conducted to determine the maximum prices to pay for inputs and the minimum prices for fattened animals and meat products. This will help people involved in the complex feedloting system to make informed decisions to optimise.

d. It will also be good to assess how economies of scale in feedloting determine profits.

ii. In promoting feed lot practices, government in partnership with private sector should develop strategies that will lead to stratification of the beef sector where the pastoralists will supply young good animals to the fatteners who in turn will supply good quality animals and beef to the other stratum namely the abattoirs, butcher shops, supermarkets and finally the consumer. Although there is cost in maintaining this beef stratum, every body involved in this stratum stands to benefit.

iii. There is a need to create awareness and institute relevant training to all stakeholders on the complex issues of beef and quality meat production including feedloting. Importance of pre-slaughter and post slaughter meat handling, ageing of meat and meat cuts.

iv. Tanzania has huge and varied feed resources which could be used in promoting and scaling up of feedloting of cattle. Deliberate efforts be carried out to optimize their use especially those not competing with human nutrition.

v. Although there were measurable differences in performance and carcass characteristics between breed and dietary treatments, the animals used in the present study had no sufficient similar background in terms of age, nutritional background, and management. It is recommended that in future similar studies more replications per treatment be used depending on availability of resources.

6.3 Areas for Further Research

This study is unique in that it is the first detailed study on feedloting of cattle in Tanzania and looked at arrays of issues including economics of fattening. The aim was to obtain the greatest quantity of high quality meat through intensified feeding. From this study, the following areas need further research:

i. The ages of animals in this study ranged from 1 to 3 years for Boran and 1.5 to 4 years for TSHZ. Young animals cost less because of lesser liveweights but require longer period and higher feed quality to reach the desired weight and finish. Older animals needs less time in the feedlot. It will be of interest to evaluate optimum age at entry and optimum finishing period of Boran and TSHZ cattle in terms of meat quality and economics of feedlot fattening.

ii. Value-adding mechanism on carcasses produced under feedlot conditions need to be studied to partially offset additional costs associated with feedlotting. One of the mechanisms is the development of primal beef cuts which should correspond closely to the beef units that a retail butcher or super markets will order from a wholesaler or abattoir. Further research be directed in market strategies suitable at the retail butchers to meet consumers requirements.

iii. Research should also be carried out to assess requirements of variety of consumers (including niche markets, hotels, mining, tourism) and their willingness to pay extra for buying quality beef meat.

iv. Due to the fact that by 10 days of ageing the meat from Tanzania breeds (Boran and TSHZ) had attained a shear force of 48. And 49.6 N for experiment 1 and 2 i.e. tender meat, it is recommended that further studies on ageing time to get exact time for tenderizing Tanzanian meat i.e. between 2 to 10 days.

REFERENCES

Abdullah. A.Y. and Musallam. H.S. (2007). Effect of different levels of energy on carcass composition and meat quality of male black goats kids. *Livestock Science* 107 (1): 70 - 80.

Albertí. P.. Ripoll, G.. Goyache, F., Lahoz. F., Olleta. J.L.. Panea. B. and Sañudo. C. (2005). Carcass characterization of seven Spanish beef breeds slaughtered at two commercial weights. *Meat Science* 71: 514 – 521.

Allen. D.M. (1992). Rationing Beef Cattle. A practical Manual. Chalcombe Publications. Caterbury. UK. 92pp.

Andersen. H.J., Oksbjerg. N. and Therkildsen. M. (2005b). Potential quality control tools in the production of fresh pork, beef and lamb demanded by the European society. *Livestock Production Science* 94 (1-2): 105-124.

Anderson. H.J., Oksbjerg, N., Young, J.F, and Thekildsen. M. (2005a). Feeding and meat quality - A future approach. *Meat Science 70:* 543-554.

Annet, S. (2005). Beef production in the Tropics: Wheat and rice straw as forage for molasses based diets. Minor field study report submitted to the Department of large animal sciences. The Royal Veterinary and Agriculture University, Denmark. 67pp.

A.O.A.C. (2000). Official Methods of Analysis, 17th Edition. Association of Official Analytical Chemists, Virginia, USA. 69-88pp.

Appleby. M.C. and Hughes. B.O. (1997). Introduction. In Animal Welfare. (Edited by Appleby. M.C. and Hughes. B.O.). Wallingford: CAB International, UK. 2-3pp

Asghar. A. and Bhatti. A.R. (1987). Endogenous proteolytic enzymes in skeletal muscle: Their significance in muscle physiology and during post-mortem *aging events* in CIUCBSSCS. *Advance Food Research* 31:343.

Ashimogo, G. and Greenhalgh, P. (2007). Trends in growth of modern retail and wholesale chains and related agribusiness in Tanzania. [http:// www.Regoverning markets. org/en/filemanager/active?fid=439] site visited on 10/09/2009.

Asizua, D., Mpairwe, D., Kabi, F., Mutetikka, D. and Madsen, J. (2009). Growth and slaughter characteristics of Ankole cattle and its Boran and Friesian crossbreds. *South African Journal of Animal Science* 39: 81-82.

Atti, N., Rouissi, H. and Mahouachi, M. (2004). The effect of dietary crude protein level on growth, carcass and meat composition of male goat kids in Tunisia. *Small Ruminants Research* 54: (1-2) 89-97.

Bailey, C.R., Duff, G.C., Cheatham, R.C., Sanders, S.R., Whitney, T.W., Mendivil, O.B., Hafliger, H.C., Henderson, D.A. and Treichel. J.L. (2004). Effects of dietary urea concentration on acid-base balance of feedlot steers fed a High concentrate steam- flaked corn based diet. In *proceedings, Western Section, American Society of Animal Science* 55: 383-385.

Barajas, R. and Zinn, R.A. (1998). The feeding value of dry-rolled and steam-flaked corn in finishing diets for feedlot cattle: influence of protein supplementation. *Journal of Animal Science* 76:1744-1752.

Belk, K.E., Scanga, J.A., Smith, G.C. and Grandin, T. (2002). The Relationship Between Good Handling / Stunning and Meat Quality in Beef, Pork, and Lamb. Paper presented at the American Meat Institute Foundation, Animal Handling And Stunning Conference on February 21-22 in [http://www.grandin.com/meat/hand.stun.relate.quality.html] site visited on 10 January 2011.

Belk, K.E., George, M.H., Tatum, J.D., Hilton, G.G., Miller, R.K., Koohmaraie, M., Reagan, J.O. and Smith, G.C. (2001). Evaluation of the Tendertec beef grading instrument to predict the tenderness of steaks from beef carcasses. *Journal Animal Science* 79: 688– 697.

Bennett, L.L., Hammond, A.C., Williams, M.J., Kunkle, W.E., Johnson, D.D., Preston, R.L. and Miller, M.F. (1995). Performance, carcass yield, and carcass quality characteristics of steers finished on rhizoma peanut (Arachis glabrata)-tropical grass pasture or concentrate. *Journal of Animal Science* 73: 1881–1887.

Berg, R.T. and Butterfield, R.M. (1976). New concepts of cattle growth. Sydney University Press. Press Bldg., University of Sydney, Australia. 1-12pp.

Bidner, T.D., Schupp, N.R., Mohamad, A.B., Rumore, N.C., Montgomery, R.E., Bagley, C.P. and Mc Millin, K.W. (1986). Acceptability of beef from Angus-Hereford or Angus-Hereford-Brahman steers finished on all forage or a high energy diet. *Journal of Animal Science* 62: 381–387.

Borggard, C., Madsen, N.T. and Thodberg, H.H. (1996). In line image analysis in the slaughter industry, illustrated by beef carcass classification. *Meat Science* 43:151-163.

Bowker, B.C., Liu, M.N., Solomon, M.B., Eastridge, J.S., Fahrenholz, T.M. and Vinyard, B. (2007). Effects of hydrodynamic pressure processing and blade tenderization on intramuscular collagen and tenderness-related protein characteristics of top rounds from Brahman cattle. *Journal of Muscle Foods* 18: 35-55.

Bowling, R.A., Riggs, J.K., Smith, G.C., Carpenter, Z.L., Reddish, R.L. and Butler, O.D. (1978). Production, carcass and palatability characteristics of steers produced by different management systems. *Journal of Animal Science* 46: 333.

Burke, R.M. and Monahan, F.J. (2003). The tenderization of shin beef using a citrus juice marinade. *Meat Science* 63: 161-168.

Butterworth, M.H. (1985). Beef cattle Nutrition and tropical pastures. Longman group limited, London. 500pp.

Braggins, T.J. (1996). Effect of stress-related changes in sheep meat ultimate pH on cooked odour and flavour. *Journal of Agricultural and Food Chemistry* 44 (88): 2352-2360.

Bruas-Reignier, F. and Brun-Bellet, J. (1996). Changes affecting the *Longissimus dorsi, Triceps brachii caput longum* and *Rectus femoris* muscle of young Friesian bulls during meat ageing. *Meat Science* 43 (3-4): 335 – 344.

Brugiapaglia, A., Destefanis, G. and Lisa, C. (2008). Influence of ethnic group, feeding plan and ageing on colour, water holding capacity and Warner-Bratzler shear of veal calves. *In 54th International Congress on Meat Science & Technology*, held in Cape Town, South Africa from 10 – 15 August, 2008.

Bwire, J.M.N., Wiktorsson, H. and Mwilawa, A.J. (2003). A feeding strategy of combining tropical grass species for stall-fed dairy cows. *Journal of Tropical Grasslands* 37: 94-100.

Casasús, I., Sanz, A., Villalba, D., Ferrer, R. and Revilla, R. (2002). Factors affecting animal performance during the grazing season in a mountain cattle production system. *Journal of Animal Science* 80: 1638–1651

Cheng, K.J., McAllister, T.A., Popp, J.D., Hristov, A.N., Mir, A., and Shin, H.T. (1998). A Review of Bloat in Feedlot Cattle. *Journal of Animal Science* 76: 299 – 308.

Christensen, M., Henckel, P. and Purslow, P.P. (2004). Effect of muscle type on the rate of post-mortem proteolysis in pigs. *Meat Science* 66: 595-601.

Christensen. M., Karlsson. A.H. and Madsen. J. (2007). Tenderness: the most important quality attribute in beef. how can it be measured? *In: Proceedings of the 2nd TSAP/TVA joint International Conference* held on 29 November to 1 December. 2007 at AICC Arusha, Tanzania. 210pp.

Christensen. M., Torngren. A.M., Gunvig. A., Rozlosnik. Lametsch. R., Harlsson. A.H. and Ertbjerg. P. (2009). Injection of marinade with actinidin increases tenderness of porcine M. bicepts femoris and affects myofibrils and connective tissue. *Journal of food Agriculture* 89. 153-158.

Cooper. R.J., Klopfenstein, T.J., Stock. R.A., Milton. C.T., Herold. D.W. and Parrott. J.C. (1999). Effects of Imposed Feed Intake Variation on Acidosis and Performance of Finishing Steers. *Journal of Animal Science* 77:1093–10991.

Creek. M.J. (1972). The Kenya Feedlot Project. *World Animal Review* 3: 23-27.

Creek, M.J. and Squire, H.A. (1976). Use of a slaughter technique for technical and economical evaluation on sugarcane and maize silage based rations. *Tropical Animal Production* 1: 56-65.

Crouse, J.D., Cundiff, L.V., Koch, R.M., Koohmaraie, M. and Seideman, S.C. (1989). Comparisons of *Bos indicus* and *Bos Taurus* inheritance for carcass beef characteristics and meat palatability. *Journal of Animal Science* 67: 2661 – 2668.

Culioli. J. (1995). Meat Tenderness: Mechanical assessment. In: Expression of tissue proteinases and regulation of protein degradation as related to meat quality. ed Ouali A, Demeyer DI, Smulders FJM. *ECCEAMST* 239-266.

Davey. C.L. and Gilbert, K.V. (1976). Temperature-dependent cooking toughness in beef. *Journal of Science of Food and Agriculture* 25: 931-938.

Das. S.M. (2009). Beef Production highlights in Tanzania. Special Ministry research report. 68pp.

Das. S.M. and Mkonyi, J.I. (2003). Important aspects of conservation of indigenous cattle in Tanzania: A review. In: *Proceedings of the Tanzania Society of Animal Production. TSAP Conference series vol* 30, (2003). (Editted by Kifaro, G.C., Laswai, G.H., Lekule, F.P., Kimambo, A.E. and Kidunda, R.S.) 28 – 30 October 2003, Tanga, Tanzania. 59 – 70pp.

Dawson, L.E.R., Carson, A.F., and Moss, B.W. (2002). Effects of crossbred ewe genotype and ram genotype on lamb meat quality from the lowland sheep flock. *Journal of Agricultural Science* 139: 195-204.

De Leeuw, P.N., Omore, A., Staal, S. and Thorpe, W. (1999). Dairy production systems in the tropics. In: Falvey, L., Chantalchana, C. (Eds.), Smallholder Dairying in the Tropics. ILRI, Nairobi, Kenya. 19–44pp.

De Sonet, S., Webb, E.C., Claeys, E., Uytterhaegen, L. and Demeyer, D.I. (2000). Effect of dietary energy and protein level on fatty acid composition of intramuscular fat in double muscled Belgian Blue bulls. *Meat Science* 56: 73-79.

Den Hertog-Meischke, M.J., Smulders, F.J.M. and van Logtestijn, J.G. (1998). The effect of storage temperature on drip loss from fresh beef. *Journal of Food Science and Agriculture* 78: 522 - 526.

Dhuyvetter, J. (1995). Beef Cattle Frame Scores. AS-1091, May 1995. Area Livestock Specialist. [http://www.ag.ndsu.edu/pubs/ansci/beef/as1091w.htm] site visited on 20/1/2010.

Diaz, M.T., Velasco, S., Caneque, V., Lauzurica, S., de Huidobro, F.R., Perez, C., Gonzalez, C. and Manzanares, J. (2002). Use of concentrate or pasture for fattening lambs and its effect on carcass and meat quality. *Small Ruminants Research* 43(3): 257-268.

Doto, S.P., Kimambo, A.E., Mgheni, D.M., Mtenga, L.A., Laswai, G.H., Kurwijila, L.R., Pereka, A.E., Kombe, R.A., Weisbjerg, M.R., Hvelplund, T., Madsen, J. and Petersen, P.H. (2004). Tanzania Feedstuff Table For Ruminants 2004. Sokoine University of Agriculture, Morogoro, Tanzania. 71pp.

Dransfield, E. (1994). Tenderness of meat, poultry and fish. In *Quality attributes and their measurement in meat, poultry and fish products.* (Edited by Pearson A.M. and Dutson, T.R. Blackie). Academic and Professional, Glascow UK. 289-315pp.

Drummond, L.S. and Sun, D.W. (2005). Feasibility of water immersion cooking of beef joints: Effect on product quality and yield. *Journal of Food Engineering* 77: 289-294.

du Plessis, I. and Hoffman, L.C. (2007). Effect of slaughter age and breed on the carcass traits and meat quality of beef steers finished on natural pastures in the arid subtropics of South Africa. *South Africa Journal of Animal Science* 37 (3): 241-246.

Earley, B. and O'Riordan, E.G. (2006). Effects of transporting bulls at different space allowances on physiological, haematological and immunological responses to a 12-h journey by road. *Irish Journal of Agricultural and Food Research* 45:39–50.

Eskildsen, C.A., Mpairwe, D., Kamatara, H., Mushi, D., Kimambo, A., Madsen, J. and Christensen, M. (2010). Effect of animal age and carcass suspension on toughness of *longissimus dorsi* from Ankole bulls. In *proceedings of the 5th All Africa Conference on Animal Agriculture* held on, 25 - 28 October, 2010 at United Nation Conference Centre, Addis Ababa Ethiopia. 110-113pp.

Fadol, S.R. and Babiker, S.A. (2010). Effect of feedlot regime on performance and carcass characteristics of Sudan Baggara zebu cattle. *Livestock Research for Rural Development* 22(2). [http://www.lrrd.org/lrrd22/2/fado22027.htm] site visited on 4/1/2010.

Falmey, M.H. (1986). Performance of crossbred beef and dairy steers finished on fast and slow gain feeding regimes. *Agriculture Canadian Canadex Publication* 420: 9-10.

FAO. (2005). Cattle production parameters of pastoral systems in sub-Saharan Africa. [http://www.fao.org/docrep/005/y4176e/y4176e0i.htm] site visited on 24/10/2009.

Ferrell, C.L. and Jenkins, T.G. (1998). Body Composition and Energy Utilization by Steers of Diverse Genotypes Fed a High-Concentrate Diet During the Finishing Period: II. Angus, Boran, Brahman, Hereford, and Tuli Sires. *Journal of Animal Science* 76:647–657.

Fiems, L.O., De Campeneere, S., Van Caelenbergh, W., De Boever, J.L. and Vanacker, J.M. (2003). Carcass and meat quality in double muscle Belgian Blue bulls and cows. *Meat Science* 63: 345-352.

Forrest, J.C., Aberle, E.D., Hedrick, H.B., Judge, M.D. and Merkel, R.A. (1975). Principles of Meat Science. W.H. Freeman and Company. New York. 310pp.

Forstrer, S.J. (2005a). Beef cattle feedlots diet formulations. [http://www2.dpi.qld.gov .au/beef/3439.html] site visited on 27/7/2009.

Forstrer, S.J. (2005b). Beef cattle feedlots –Feed consumption and liveweight gain. [http://www2.dpi.qld.gov .au/beef/3441.html] site visited on 26/10/2009.

French, P., O'Riordan, E.G., Monahan, F.J., Caffrey, P.J., Mooney, M.T., Troy, D.J. and Moloney, A.P. (2001). The eating quality of meat of steers fed grass and / or concentrates. *Meat Science* 57: 379-386.

Frylinck, L., Strydom, P.E. and Scholtz, M.M. (2006). Benchmarking the feedlot performance and meat quality of indigenous cattle genotypes in South Africa. *In proceedings of the 4th AACA and 31st TSAP* Annual meeting held at AICC in Arusha Tanzania. 231-237pp.

Fukumoto, G.K., Kim, Y.S., Oduda, D. and Ako, H. (1995). 'Chemical composition and shear force requirement of loin eye muscle of young, forage-fed steers. *Research Extension Series* 161: 1-5.

Gerelt, B., Ikeuchi, Y. and Suzuki, A. (2000). Meat tenderization by proteolyitic enzymes after osmotic dehydration. *Meat Science* 56: 311-318.

Glitsch, K. (2000). Consumer perception of fresh meat quality: cross-national comparison. *British Food Journal* 102: 177-194.

Goering, H.K. and Van Soest, P.J. (1991). Forage fibre analyses (Apparatus, reagents procedures and some application). USDA Agricultural handbook. Department of Agriculture, Washington DC, USA. 379pp.

Goll, D.E., Thompson, V.F., Li, H., Wei, W.E.I. and Cong, J. (2003). The Calpain System. *Physiology Review* 83 (3): 731-801.

Grandin, T. (2000). Handling And Welfare Of Livestock In Slaughter Plants. In: *Livestock Handling and Transport.* (Edited by T. Grandin). CABI Publishing, New York. 409-439pp.

Grandin, T. (2010). Auditing animal welfare at slaughter plants. In proceedings of the 56th International Congress of Meat Science and Technology (56th ICoMST). *Meat Science* 86 (1): 56-65.

Hale, D.S., Goodson, K. and Savell, J.W. (1998). Beef Quality and Yield Grades. Department of Animal Science, Texas Agricultural Extension Service. [http://extension.usu.edu/cyberlivestock/files/uploads/beef3.pdf] site visited on 15/07/2009.

Hammond, J., Jr. Mason, I.L. and Robinson, T.J. (1971). Hammonds Farm Animals. 4th Edition. London. 293pp.

Hanekom, Y. (2010). The effect of extensive and intensive production systems on the meat quality and carcass characteristics of Dohne Merino lambs. Dissertation for Award of Msc Degree at Stellenbosch University, Germany. 144pp.

Haule, M.E, Laswai, G.H., Mwaseba, D.L., Kimambo, A.E., Madsen, J., Mtenga, L.A. and Mwilawa, A.J. (In press). An assessment of attitude towards selling livestock among the pastoralists in Ngorongoro district of Tanzania. In proceedings of the *5th All Africa Conference on Animal Agriculture* held on 25-28 October2010 at United Nation Conference Centre, Addis Ababa, Ethiopia.

Hennessy, D.W., Morris, S.G. and Allingham, P.G. (2001). Improving the pre-weaning nutrition of calves by supplementation of the cow and/or the calf while grazing low quality pastures 2. Calf growth, carcass yield and eating quality. *Australian Journal of Experimental Agriculture* 41: 715–724.

Henning, P.H. (1999). The Feeding Program. Feedlot Management Handbook. ANPI, Agriculture Research Council (ARC), South Africa. 96pp.

Herlocker, D. (1999). Rangeland resource in Eastern Africa, their Ecology and Development. Published by Germany Technical Co-operation. GTZ. 213pp.

Hopkins, D.L. and Thompson, J.M. (2002). Factors contributing to proteolysis and disruption of myofibrillar proteins and the impact on tenderisation in beef and sheep meat. *Australian Journal of Agricultural Research* 53: 149-166.

Hornick, J.L., Van Eenaeme, C., Diez, M., Minet, V. and Istasse, L. (1998). Different periods of feed restriction before compensatory growth in Belgian Blue bulls: II. Plasma metabolites and hormones. *Journal of Animal Science* 76:260–271.

Huhtanen, P., Ahvenäjarvi, S., Weisbjerg, M.R. and Nørgaard, P. (2006). Digestion and Passage of Fibre in Ruminants. In Sejrsen K., T. Hvelplund and M.O. Nielsen (Ed). Ruminant Physiology: Digestion, Metabolism and Impact of Nutrition on gene expression, immunology and stress. In *Proceedingsof the X^{th} ISRP*. Wageningen Academic Publishers. 87-135pp.

Hwang, I.H. and Thompson, J.M. (2001). The effect of Time and type of electrical stimulation on the calpain system and meat tenderness in beef longissimus dorsi muscle. *Meat Science* 59(2): 135-144.

ILRI (International Livestock Research Institute) (2003). Livestock marketing in Ethiopia: A review of structure, performance and development initiatives. *Socio economics and Policy Research*. Working paper issue No. 52. 34pp.

Immonen, K., Ruusunen, M., Hissa, K. and Puolanne, E. (2000). Bovine muscle glycogen concentration in relation to finishing diet, slaughter and ultimate pH. *Meat Science* 55: 25-31.

Jama, N., Muchenje, V., Chimonyo, M., Strydom, P.E. and Dzama, K. (2007). Cooking loss components of beef from three cattle breeds raised in a low input cattle production system. In *54th International Congress on Meat Science and Technology*, held on 10 – 15 August in Cape Town, South Africa.160-162pp.

Jayasooriya, S.D., Torley, P.J., D'Arcy, B.R. and Bhandari, B.R. (2007). Effect of high power ultrasound and ageing on the physical properties of bovine *Semitendinous* and *Longissimus* muscle. *Meat Science* 75: 628 - 639.

Jepsen, O. and Creek, M.J. (1976). Comparative Fattening Performance of Two Types of Cattle in Ethiopia. *World-Review-of-Animal-Production* 12(1): 4-8, 83-90pp.

Jeremiah, L.E. and Gibson, L.L. (2003). The effect of dietary poultry litter supplementation on beef chemical, cooking, and palatability properties and consumer acceptance. *Food Research International* 36: 943-948.

Jeremiah, L.E., Tong, A.K.W. and Gibson, L.L. (1998). The influence of lamb chronological age, slaughter weight, and gender. Flavor and texture profiles. *Food Research International* 31(3): 227-242.

Johnson, P.L., Purchas, R.W., Mcewan, J.C. and Blair, H.T. (2005). Carcass composition and meat quality differences between pasture-reared ewe and ram lambs. *Meat Science* 71: 383-391.

Jones, S.D.M., Newman, J.A., Tong, A.K.W., Martin, A.H. and Robertson, W.M. (1984). Feedlot performance, carcass composition and efficiency of muscle gain in bulls and steers of difference mature size slaughtered at similar levels of fatness. *Canadian Journal of Animal Science* 64: 621.

Kerth, C.R., Barden, K.W., Cox, R., Kerth, L.K. and Rankins, J. (2007). Carcass sensory, fat colour and consumer acceptance characteristics of Angus-cross steers finished on ryegrass (*Lolium multiflorum*) forage or on a high-concentrate diet. *Meat Science* 75(2): 324-331.

Kilpatrick, D.J. and Steen, R.W.J. (1999). A predictive model for beef cattle growth and carcass composition. *Agricultural Systems* 61(2): 95-107

Kimambo, A.E., Mtenga, L.A., Laswai, G.H., Mgheni, D.M. and Mwilawa, A. J. (2010). Beef fattening and value addition. IGMAFU meat Project –DASP-SUA, Tanzania. 36pp.

Kimambo, A.E., Laswai, G.H., Hansen, H.H., Mgheni, D.M., Mtenga, L.A. and Marstrand, M. (2004). Status of natural resource base and livestock banking. [http://www.ihh.kvl.dk/livestockbank/appendixV_Kimambo.pdf] sited visited on 2/3/2009.

Kinunda-Rutashobya, L. (2003). Market demand survey for the Dodoma abattoir. Final report. Tanzania Livestock Marketing Project. Dar es Salaam, Tanzania. 49pp.

Knoblich. H.V., Fluharty, F.L. and. Loerch, S.C. (1997). Effects of programmed Gain Strategies on Performance and carcass characteristics of steers. *Journal of Animal Science* 75: 3094-3102.

Koch, R.M., Dikeman, M.E. and Crouse, J.D. (1982). Characterization of biological types of cattle (Cycle III). III. Carcass composition, quality and palatability. *Journal of Animal Science* 54:35.

Koohmaraie, M. (1988). The role of endogenous proteases in meat tenderness. Re. Meat Conference. In proceedings of the Reciprocal Meat Conference. 41:89–100.

Koohmaraie. M. (1994). Muscle proteinases and meat aging. *Meat Science* 36: 93-104.

Koohmaraie, M. (1996). Biochemical factors regulating the toughening and tenderization process of meat. *Meat Science* 43(s): 193–201.

Koohmaraie, M., Kent, M.P., Shachelford, S.D., Veiseth, E. and Wheeler, T.L. (2002). Meat tenderness and muscle growth: is there any relationship. *Meat Science* 62: 345-352.

Kristensen, L., Therkildsen, M., Riis, B., Sorensen, M.T., Oksbjerg, N., Purslow, P.P. and Ertbjerg, P. (2002). Dietary-induced changes of muscle growth rate in pigs: effects on *in vivo* and post-mortem muscle proteolysis and meat quality. *Journal of Animal Science* 80 (11): 2862 – 2871.

Kurwijila, R.L. and Kifaro, G.C. (2001). An overview of Biodiversity of Livestock in Tanzania. In: *Proceedings of SUA-MU ENRECA Project* workshop. (Editted by Kifaro, C. G., Kurwijila, R. L., Chenyambuga, S. W. and Chilewa, P. R.). 6th August, 2001, TANESCO Training Institute, Morogoro.Tanzania. 2-26 pp.

Laswai, G.H., Mutayoba, S.K., Temu, A.A. and Kusolwa, P.M. (2000). Chemical composition of poultry feedstuffs in Tanzania: *Feed Table*. SUA and ASARECA/FOODNET project. 24pp.

Lawrence, T.L.J. and Fowler, V.R. (1997). Growth of Farm Animals. CAB International. New York, USA.

Lawrie, R.A. and Ledward, D.A. (2006). The eating quality of meat. In: Lawries meat science, 7th edition. Woodhead, Cambrigdge, England. 279-341pp.

Lefaucheur, L., Ecolan, P., Plantard, L. and Gueguen, N. (2002). New insights into muscle fiber types in the pig. *Journal of Histochemistry Cytochemistry* 50: 719-730.

Lepetit, J. and Culioli, J. (1992). Mechanical Properties of Meat. *Meat Science* 36: 203-237.

Lewis, G.J., Purslow, P.P. and Rice, A.E. (1991). The effect of conditioning on the strength of perimysial connective tissue dissected from cooked meat. *Meat Science* 30:1-12.

Longino, M. (2007). A study on performance of three breeds of cattle on high molasses based diet under feedlot condition. A special project report submitted in partial fulfilment of the requirement of the degree of Bachelor of Science at DASP, SUA. 42pp.

Luziga, A.P.B. (1996). Increasing beef output through changes of livestock production systems in Tanzania and their limitations. *Management in Modern Livestock. Food Business*. Nordisk Landboskole, Odense. Denmark. 125pp.

Luziga, A. (2005). Mtibwa Feedlot Project. *Annual Research Report* from July to September 2004 to September. 24pp.

Macha, A.M., Getz, W.R. and Mchau, K.W. (1988). An investigation of breeds and breeding systems for use in commercial beef production. In proceedings of the first TALIRO Conference 17-19 February, Arusha. 110pp.

Madsen, J. (2005). Income Generation through Market Access and improved Feed Utilization production of quality beef and goat meat (IGMAFU -meat). Project description. DANIDA funded Project. Copenhagen, Denmark. 68pp.

Madsen, J., Kimambo, A., Mtenga, L.A., Larsen, C.S., Hvelplund, T. and Weisbjerg, M. (In press). The Importance of Beef Production Systems as a Contributor Towards Achieving Millennium Development Goals. *In: Proceedings of the 2nd TSAP/TVA Joint International Conference* held on 29 November to 1 December, 2007 at AICC Arusha, Tanzania.

Madsen, J., Hvelplund, T., Weisbjerg, M.R., Mlay, P.N.S., Kimambo, A.E., Mtenga, L. A., Laswai, G.H. and Mgheni, D.M. (2004). What are optimum rations for livestock? In: *Proceedings of the 31st Scientific Conference. Tanzania Society of Animal Production Annual Conference held on* 5 - 7 October, Moshi. Tanzania. 51 – 59pp.

Madsen, N.T. (2002). Danish Meat Association Classification in Denmark. The Danish Experience with the S-EUROP system. [http://www.dmri.dk/Slagteri_og_Foraedling/Produktkvalit/Klassificerin/ Publikationer/ Classi_in_DK.aspx.] site visited on 20 November 2007.

MAFS (Ministry of Agriculture and Food security), (2003). Beef cattle husbandry training manual and tutors guide. Instructional material Developemnt Unit/ASPS. *Technical handbook* No. 9. 196 pp.

Magalhães, K.A., Valadares Filho, S.C., Paulino, P.V.R., Paulino, M.F. and Valadares, R.F.D. (2006). Performance, digestibility and carcass characteristics of feedlot dairy steers fed diets with different urea levels. *Arq. Bras. Medicinal Vetelinarie Zootec.* 58(5): 860-867.

Malope, P., Tsopito, C.M., Aganga, A.A. and Madibela, O.R. (2007). Profitability of dry season beef feed-lotting in grain deficit countries: the case of Botswana. *Livestock Research for Rural Development.* 19:81. http://www.lrrd.org/lrrd19/6/malo19081.htm] site visited on 22 April.

Maltin, C., Balcerzak, D., Tilley, R. and Delday, M. (2003). Determinants of meat quality: tenderness. *Nutrition Society* 62(2): 337-347.

Mapunda, F. (2007). A case study on the existing and potential market opportunities for quality beef in Tanzania. Dissertation for Award of MSc Degree at Sokoine University of Agriculture, Morogoro, Tanzania. 135pp.

María, G.A., Villarroel, M. Sanudo, C., Olleta, J.L. and Gebresenbet, G. (2003). Effect of transport time and ageing on aspects of beef quality. *Meat Science* 65: 1335 – 1340.

Marinova, P., Banskalieva, V., Alexandrov, S., Tzvetkova, V. and Stanchev, H. (2001). Carcass Composition of whole carcass and non-carcass portion of goats and sheep. *South Africa Journal of Animal Science* 34: 81-84.

Marsh, B.B., Ringkob, T.P., Russell, R.L., Swartz, D.R. and Pagel, L.A. (1988). Mechanisms and strategies for improving meat tenderness. *Reciprocal Meat Conference Proceedings* 41: 113 – 118.

Mawona, F. (2009). Feedlot performance under different practices in Mwanza region. Dissertation for Award of MSc Degree at Sokoine University of Agriculture, Morogoro, Tanzania. 146pp.

McDonald, P., Edwards, R.A., Greenhalgh, J.F.D. and Morgan, C.A. (2002). Animal nutrition. Sixth Edition Ashford Colour Press Ltd., Gosport. 693pp.

McGee, M., Keane, M.G., Neilan, R., Moloney, A.P. and Caffrey, P.J. (2007). Body and carcass measurements, carcass conformation and tissue distribution of high dairy genetic merit Holstein, standard dairy genetic merit Friesian and Charolais × Holstein Friesian male cattle. *Irish Journal of Agricultural and Food Research* 46(2): 20-27.

McKeith, F.K., Savell, J.W., Smith, G.C., Dutson, T.R. and Carpenter, Z.L. (1985). Physical, chemical, histological and palatability characteristics of muscle from three breed types of cattle at different times on feed. *Meat Science* 15:37.

Meissner, H.H., Smuts, M. and Coertze, R.J. (1995). Characteristics and efficiency of fast- growing feedlot steers fed different dietary energy. *Journal of Animal Science* 73: 931-936.

Melody, J.L., Lonergan, S.M., Rowe, L.J., Huiatt, T.W., Mayes, M.S. and Huff-Lonergan, E. (2004). Early post-mortem biochemical factors influence tenderness and water-holding capacity of three porcine muscles. *Journal of Animal Science* 82: 1195-1205.

Mero, R.N. and Udén, P. (1998). Promising tropical grasses and legumes as feed resources in Central Tanzania. VI. Nitrogen balance in growing bulls consuming tropical herbaceous forage legumes. *Animal Feed Science Technology* 72: 387–396.

Mgheni, D.M., Hvelplund, T. and Weisbjerg, M.R. (1994). Intestinal Digestibility of Rumen Undegraded Dietary Protein from Tropical Roughages Estimated by the _Mobile Bag Technique. *Animal Science* 44 (4): 230-235.

Mitsumoto, M., Arnold, R.N., Schaefer, D.M. and Cassens, R.G. (1995). Dietary Vitamin E Supplementation Shifted Weight Loss from Drip to Cooking Loss in Fresh Beef Longissimus During Display. *Journal of Animal Science* 73: 2289-2294.

MLA (Meat and Livestock in Australia) (2006). Sweet gains from high-molasses feedlot diets. [http://www.bundysugar.com.au/molasses/molasses.html] site visited on 10/11/2009.

MLA (Meat and Livestock in Australia) (2002). The effect of pH on goatmeat eating quality. Animal Health and Welfare. [http://books.google.com/books/about/ Proceedings_of_National_Beef_Genetics_Wo.html?id=PxUiAAAACAAJ] site visited on 4/06/2010.

MLDF (Ministry of Livestock Development and Fisheries) (2009). Livestock Investment opportunities. [http://www.mifugo.go.tz/livestock_resources/ index.php] site visited 11/05 /2010.

Mkonyi, P.A., Makungu, L.S., Shigi, K., Kipanga, C., Mihayo, E.J., Palangyo, E. and Lambo, S. (2006). The experience of farmers with cotton seed hulls as primary feed material in cattle feedlots in Mwanza and Shinyanga Regions of Tanzania. In: *Proceedings of the Tanzania Veterinary Association* held 12-15 December at AICC, Arusha, Tanzania. 179pp.

Mpairwe, D.R., Katongole, C., Bareeba, F.B., Mukasa-Mugerwa, E. and Ebong, C. (2003). Effect of plane of nutrition on growth performance and carcass characteristics of growing Ankole, N'ganda, and crossbred (Friesian x Ankole) bulls and their potential for beef cattle fattening in Uganda. *In proceedings of the 30th TSAP Scientific conference*, 4H Centre-Tanga, Tanzania. 179-199pp.

MPK (Meat Production in Kenya) (2005). Export processing zones Authority. [www.epzakenya.com] site visited in 20 September, 2009.

Mpiri, D.B. (1990). Advances in cattle breeding in Tanzania. Ministry of Agriculture, Tanzania. Ministry Special Report. 85pp.

Mpiri, D.B. (1991). Managing improved cattle in Semi-arid areas: The experiences of Kondoa and Mpwapwa Districts. 149pp.

Mpiri, D.B. (1994). Improving cattle productivity in Tanzania. Ministry Department of Research and Training Dar es Salaam. 251 pp.

Mohammed, T.A., El-Tayeb, A.E., Mustafa, A.F. and Khogali, H.M. (2008). Processed and unprocessed sorghum Stover in beef finishing rations. [http://www.fao.org/wairdocs/ilri/x5490e/x5490e0q.htm] site visited on 7/7/2008.

Monsóon, F., Sañudo, C. and Sierra, I. (2004). Influence of cattle breed and ageing time on textural meat quality. *Meat Science* 68: 595–602.

Moran, J.B. and Wood, J.T. (1986). Comparative performance of Indonesian Large Ruminants 3. Growth and development of carcass tissues. *Australian Journal of Agricultural Research* 37(4): 435 – 447.

Morgan, T.H. Montgomery, K., Belk, E. and Smith, G.C. (2002). 'National Beef Quality Audit–2000: Survey of targeted cattle and carcass characteristics related to quality, quantity, and value of fed steers and heifers. *Journal of Animal Science* 80: 1212-1222.

MRNL (Meat research news letter) (1985). Liveweight and carcass weight loss in cattle. CSIRO Division of food research. *Meat Research Laboratory* no 85/1 4 January. 35pp.

Msanga, N.Y. and Bee, J.K.A. (2006). The performance of Friesian x Boran bulls managed extensively under agropastoralism with indigenous Tanzanian zebu. *Livestock Research for Rural Development* 18:20. [http://www.lrrd.org/lrrd18/2/msan18020.htm] site visited on 22/4/2011.

Msanga, Y.N., Mbaga, S.H. and Msechu, J.K. (2001). Farm animal breeds and Strains of Tanzania. In *Proceedings of SUA-MU ENRECA Project Workshop.* (Edited by Kifaro, C. G., Kurwijila, R. L., Chenyambunga, S.W. and Chilewa, P.R.) 6th August, 2001, Morogoro, Tanzania. 36 – 49pp.

Mtengeti, E.J., Magne Mo, Phiri, E.C.J., Chibunda, R.T., Laswai, G.H.. Urio. N.A.. Percka, A.E., Mtenga, L.A., Mbwile, R., Mgasa, M.N., Muhikambele. V.R.. Israeli, S.H., Mwakilembe, A. and Ayo, E. (2006). Effects of regrowth period. season and harvesting frequency on the yield and nutritive value of *Chloris gayana* in the southern highlands of Tanzania. *African Journal of Range & Forage Science* 23(2): 107–111.

Mushi, D.E. (2009). Strategies for improving quality of meat produced from lambs and goats in Norway and in Tanzania – Influenced of species, breed, sex, age and diet. *PhD Thesis*, No 2009:9.

Mushi, D.E., Mtenga, L.A. and Eik, L.O. (2007). Some factors affecting the quality of meat from ruminants and their relevance to the Tanzanian meat industry. *Tanzania Journal of Agriculture Science* 8(2): 173 – 192.

Mushi, D.E., Mtenga, L.A., Kifaro, G.C. and Eik, L.O. (2009). Effects of concentrate levels on fattening performance, carcass and meat quality attributes of small East African x Norwegian crossbred goats fed low quality grass hay. ***Livestock Science*** [doi:10.1016/j.livsci.2009.01.012] site visited on 2/. 8pp.

Mushi, D.E., Mtenga, L.A., Eik, L.O., Safari, J. and Mwilawa, A.J. (2006). Some factors affecting the quality of meat from ruminants and their relevance to the Tanz*anian meat industry. **In proceeding of the Tanzanian Society of Animal Production*** held at The Crene Hotel Moshi, Tanzania. 32: 45-52.

Mwatawala, H.W. and Kifaro, G.C. (2001). Compartive growth performance of Tanzania shorthorn zebu, Boran and their crosses in Tanzania. 2. Growth rates, Heterosis and Phenotypic correlations. In: *Proceedings of SUA-MU ENRECA Project workshop* held on 6 August, 2001 at TANESCO Training Institute, Morogoro, Tanzania. (Editted by Kifaro, C.G., Kurwijila, R. L., Chenyambuga, S.W. and Chilewa, P.R.). 122- 134 pp.

Mwatawala, H.W. (2001). Comparative growth and reproductive performance of Tanzania shorthorn zebu, Boran and their crosses in Tanzania. Dissertation for Award of MSc Degree at Sokoine University of Agriculture, Morogoro, Tanzania. 195pp.

Mwilawa, A.J. (1996). Traditional Rangelands Resource Utilization among the Gogo and Maasai pastoralists Communities of Tanzania. Dissertation for Award of MSc Degree at the University of Nairobi, Kenya. 178pp.

Mwilawa, A.J. (2004). Ecological Impact and Politics on Pastoral sedentarization: A case of Central and central-eastern Tanzania. In *proceedings of the symposium on Trees, Rain and Climate* held on 30 September – 1 October at Oxford University. 345pp.

Mwilawa, A.J., Kimambo, A.E., Mtenga, L.A., Madsen, J., Hvelplund, T., Weisbjerg, M.R., Laswai, G.H. Christensen, M. and Mgheni, D.M. (In press). Production of quality beef in Tanzania: fattening trial at Kongwa ranch – on going. In *Proceedings of the 2nd TSAP/TVA joint International Conference* held on. 29 November to 1 December, 2007 at AICC Arusha, Tanzania.

Nalaila, S.M. (2005). Phenotypic characterization and slaughter characteristics of Iringa red zebu cattle. Dissertation for Award of MSc Degree at Sokoine University of Agriculture, Morogoro, Tanzania. 68-75pp.

Nandonde, S.W. (2008). Assessment of the availability of major resources for production of beef in Tanzania. Dissertation for Award of MSc Degree at Sokoine University of Agriculture, Morogoro, Tanzania. 111pp.

Ngere, L.O. (1985). Review of White Fulani (Bunaji) in Nigeria. In: *Proceedings of the OAU Expert Committee Meeting on Animal Genetic Resources in Africa.* 24 - 28 November 1983, Bulawayo, Zimbabwe. 67 – 77pp.

Ngapo, T.M. and Dransfield, E. (2006). British consumers preferred fatness levels in beef: Surveys from 1955, 1982 and 2002. *Food Quality and Preference* 17 (5): 412-417.

Nishimura, T., Liu. A., Hattori, A. and Takahashi, K. (1998). Changes in mechanical strength of intramuscular connective tissue during post-mortem aging of beef. *Journal of Animal Science* 76 (2): 528-532.

Nijthavorn, C. (1995). Effects of feeding cotton seed meal to male dairy calves on growth, carcass quality and cost of production. Kasetsart University Library. Bangkok, Thailand. 234pp

Njombe. A.P. and Msanga. Y.N. (2009). Livestock and Dairy industry development in Tanzania. Department of Livestock Production and Marketing Infrastructure Development. Ministry of Livestock Development reports. [http://www.mifugo.go.tz/livestock] site visited on 16/5/2009.

Norris, D., Macala, J., Makore, J. and Mosimanyana. B. (2002). Feedlot performance of various breed groups of cattle fed low to high levels of roughage. *Livestock Research for Rural Development* 14: 1-10.

Notter, D.R., Kelly, R.F. and Berry, B.W. (1991). Effects of Ewe Breed and Management- System on Efficiency of Lamb Production .3. Meat Characteristics. *Journal of Animal Science* 69(9): 3523-3532.

NRC (Nutrient requirements of cattle) (2003). National Academy Press. Washington, DC.

Olfaz, M., Ocak, N., Erener, G., Cam, M.A. and Garipoglu, A.V. (2005). Growth, carcass and meat characteristics of Karayaka growing rams fed sugar beet pulp, partially substituting for grass hay as forage. *Meat Science* 70: 7-14.

Oliván, M., Martínez, A., García, P., Noval, G. and Osoro, K. (2001). Estimation of the carcass composition of the yearling bulls of "Asturiana de los Valles" breed from the dissection of a rib joint. *Meat Science* 57: 185-190.

Oliván, M., Martínez, A., Osoro, K., Sañudo, C., Panea, B., Luis Olleta, J., Campo. M., Oliver, M., Serra, X., Gil, M. and Piedrafita, J. (2004). Effect of muscular hypertrophy on physico-chemical, biochemical and texture traits of meat from yearling bulls. *Meat Science*. 68 (4): 567-575.

O'Mara, F.M., Williams, S.E., Tatum, J.D., Hilton, G.G., Pringle, T.D. and Williams, F.L. (2009). Prediction of Slaughter Cow Composition Using Live Animal and Carcass Traits. [http://www.beefcowcalf.com/pubs/Topics/Production_Management/Cull_Cow _ Management] site visited on 16/7/2009.

O'Sullivan, A., O'Sullivan, K., Galvin, K., Moleney, A.P., Troy, D.J. and Kerry, J.P. (2004). Influence of concentrate composition and forage type on retail packaged beef quality. *Journal of Animal Science* 82(8): 2384-2391.

Osman, A.H. (1985). Review of Butana and Kenana breeds. In *Proceedings of the OAU expert Committee meeting on Animal Genetic Resources in Africa* held on 24 – 28 November 1983 in Bulawayo,Zimbabwe. 67 – 77pp.

Osuji, P.O. (1999). Animal feeds, feeding and sustainable livestock production. Sustainable Agriculture Solutions Action Report. The Novello press ltd, London 5:230-234.

Otte, J. and Chilonda, P. (2002). Cattle and small ruminant production systems in sub-Saharan Africa: A systematic review. FAO, Rome, Italy. 72pp

Owens. F.N. and Gardner, B.N. (2000). A review of the impact of feedlot management and nutrition on carcass measurements of feedlot cattle. *Journal of Animal Science* 77:1-18.

Owens. F.N.. Gill, D.R., Secrist, D.S. and Coleman, S.W. (1995). Review of some aspects of growth and development of feedlot cattle. *Journal of Animal Science* 73: 3152 – 3172.

Owens. F.N., Dubeski, P. and Hanson, C.F. (1993). Factors that alter the growth and development of ruminants. *Journal of Animal Science* 71: 3138-3150.

Paynne. W.J.A. (1990). An introduction to animal husbandry in the tropics. Fourth Edition Longman Group. UK Limited. 881 pp.

Pethick, D.W., Harper, G.S. and Oddy, V.H. (2004). Growth, development and nutritional manipulation of marbling in cattle: a review. *Australian Journal of Experimental Agriculture* 44 (7): 705-715.

Platter, W.J., Tatum, J.D., Belk, K.E., Chapman, P.L., Scanga, J.A. and Smith, G.C. (2003). Relationship of consumer sensory ratings, marbling score, and shear force value to consumer acceptance of beef strip loin steaks. *Journal of Animal Science* 81: 2741-2750.

Prativi, N.M.W., Murray, P.J. and Taylor, D.G. (2004). The fatty acid composition of muscle and adipose tissue from entire and castrated male Boer goats raised in Australia. *Animal Science* 79: 221-229.

Pratiwi, N.M.W., Murray, P.J. and Taylor, D.G. (2007). Feral goats in Australia: a study on the quality and nutritive value of their meat. *Meat Science* 75: (1) 168-177.

Preston, T.R. and. Wills, M.B. (1974). Intensive beef production. Second revised edition. Elsevier Science and Technology. 425pp.

Purchas, R.W., Yan, X. and Hartly, D.G. (1999). The influence of the period of ageing on the relationship between ultimate pH and shear values of beef *M. longissimus* thoracic. *Meat Science* 51: 135-141.

Purslow, P.P. (2005). Intramuscular connective tissue and its role in meat quality. *Meat Science* 70: 435 – 447.

Purslow, P.P. (2002). Meat as a raw material COMPEDIUM. The Royal veterinary and Agricultural University. Department of Dairy and Food science. 225pp.

Razminowicz, R.H., Kreuzer, M. and Scheeder, M.R.L. (2006). Quality of retail beef from two grass based production system in comparison with conversional beef. *Meat Science* 73: 351-361.

Reppert, J.N., Hughes, R.L. and Duncan, D.A. (1962). Vegetation measurements and sampling. Herbage yields and its correlation with other plant measurements. *In Range Research Methods*, USAD. 940: 15-21pp.

Robelin, I. and Geay, Y. (1984). Body composition of cattle as affected by physiological states, breed, sex and diet. Herbivore Nutrition. (Edited by Gilchrist, F.M.C. and Mackie, R I.). South Africa. 87pp.

Rosenvold. K., Petersen, J.S., Laerke, H.N., Jensen, S.K., Therkildsen, M., Karlsson, A. H., Moller, H.S. and Andersen, H.J. (2002). Muscle glycogen stores and meat quality as affected by strategic finishing feeding of slaughter pigs. *Journal of Animal Science* 79: 912 – 918.

Safari, J., Mushi, D.E., Mtenga, L.A., Kifaro, G.C. and Eik, L.O. (2011). Growth, carcass yield and meat quality attributes of red Maasai sheep fed wheat straw-based diets. *Tropical Animal Health Production*. 43(1):89-97.

Safari, J., Mushi, D.E., Mtenga, L.A., Kifaro, G.C. and Eik, L.O. (2009). Effects of concentrate supplementation on carcass and meat quality attributes of feedlot finished small East African goats. *Livestock Science* 125: 266-274.

Sambali, J.J. (2010). Attitude of Agro-pastoralists towards selling livestock in Chamwino District of Dodoma, Tanzania. Dissertation for Award of MSc Degree at Sokoine University of Agriculture, Morogoro, Tanzania.152pp.

Sañudo, C., Sanchez, A. and Alfonso, M. (1998). Small ruminant production systems and factors affecting lamb meat quality. *Meat Science* 49: s29-s 64.

Santos-Silva, J., Mendes, I.A. and Bessa, R.J.B. (2002). The effect of genotype, feeding system and slaughter weight on the quality of light lambs - 1. Growth, carcass composition and meat quality. *Livestock Production Science* 76 (1-2): 17-25.

Savell, J.W. and Cross, H.R. (1988). The role of fat in the palatability of beef, pork, and lamb. In: *Designing foods, Animal Product Options in the market place*. National Academy Press, Washington D.C., USA. 34-355pp.

Savell, J.W., Mueller, S.L. and Baird, B.E. (2005). The chilling of carcasses. *Meat Science* 70 (3): 449-459.

SAS, 2002. SAS User Guide Statistics. Version 9.2 edition. SAS Institute, INC, Carry, NC. USA. 245pp.

Sauvant, D., Perez, J.M. and Tran, G. (2004). Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers. 304 pp.

Schaake, S.L., Skelly, G.C., Halpin, E., Grimes, L.W., Brown, R.B., Cross, D.L. and Thompson, C.E. (1993). Carcass and meat sensory traits of steers finished on fescue and clover, summer forage, or for different periods in drylot. *Journal of Animal Science* 71: 3199-3205.

Schoonmaker, J.P., Loerch, S.C, Fluharty, F.L., Zerby, S.C., Zerby, H.N. and Turner, T. B. (2002). Effect of age at feedlot entry on performance and carcass characteristics of bulls and steers. *Journal of Animal Science* 80: 2247-2254.

Sentandreu, M.A., Coulis, G. and Ouali, A. (2002). Role of muscle endopeptidases and their inhibitors in meat tenderness. *Trends in Food Science & Technology* 13(12): 400-421.

Shackelford, S.D., Koohmaraie, M., Cundiff, L.V., Gregory, K.E., Rohrer, G.A. and Savell, J.W. (1994). Heritabilities and Phenotypic and Genetic Correlations for Bovine Post rigor Calpastatin Activity, Intramuscular Fat-Content, Warner-Bratzler Shear Force, Retail Product Yield, and Growth-Rate. *Journal of Animal Science* 72: 857-863.

Shackelford, S.D., Wheeler, T.L. and Koohmaraie, M. (1997). Tenderness Classification of Beef: I. Evaluation of Beef Longissimus shear force at 1 or 2 days Post-mortem as a Predictor of Aged Beef Tenderness. *Journal of Animal Science* 75:2417–2422.

Shija, D.S., Mwilawa, A.J., Laswai, G.H., Kimambo, A.E., Mtenga, L.A. and Mgheni, D.M. (*In press*). Evaluation of carcass composition of two breeds of steers finished under different dietary treatments. *In proceedings of the 33rd TSAP International Conference*, 24 - 25 September, 2009, Mwanza, Tanzania.

Skunnum, P., Chantalakhana, C., Pungchai, R., Poondusiy, T. and Prucsasri, P. (2002). Comparative feeding male dairy, beef cattle and Swamp Buffalo 1. Economics of Beef Production. *Asian-Australian, Journal of Animal Science* 15(6): 878-883.

Simmons, N.J., Young, O.A., Dobbie, P.M., Singh, K., Thompson, B.C. and Speck, P. A. (1997). Post-mortem calpain-system kinetics in lamb: Effects of clenbuterol and pre-slaughter exercise. *Meat Science* 47 (1-2): 135 – 146.

Sinclair, K.D., Lobley, G.E., Horgan, G.W., Kyle, D.J., Porter, A.D., Matthews, K.R., Warkup, C.C. and Maltin, C.A. (2001). Factors influencing beef eating quality 1. Effects of nutritional regimen and genotype on organoleptic properties and instrumental texture. *Animal Science* 72: 269-277.

Slabbert, N., Campher, J.P., Shelby, T., Leeuw, K.J, Kuhn, G.P. and Meissner, H.H. (1992). The influence of dietary energy concentration and feed intake level on feedlot steers. 3. Carcass composition and tissue growth as influenced by rate of gain. *South African Journa of Animal Science* 22: 107- 115.

Smulders, F.J.M., Toldrá, F., Flores, J. and Prieto, M. (1992). New technologies for meat and meat products. Utrecht, The Netherlands: 182-188pp.

Suliman, G.M. and Babiker, S.A. (2007). Effect of Diet-protein source on lamb fattening. *Research Journal of Agriculture and Biological Sciences* 3(5): 403 – 408.

Strudsholm, F., Aaes, O., Madsen, J., Kristensen, V.F., Andersen, H.R., Hvelpund, T. and Østergaard, S. (1999). Danish Nutrient recommendations for cattle. 84: 34

Strydom, P.E., Frylinck, L. and Smith, M.F. (2005). Should electrical stimulation be applied when cold shortening is not a risk? *Meat Science* 70: 733–742.

Strydom, P.E., Nude, R.T., Smith, M.F., Schultz, M.M. and Vandyke, J.B. (2000). Characterization of indigenous African Cattle breeds in relation to meat quality traits. *Meat Science* 55: 79 - 88.

Tarrant, P.V., Kenny, F.J., Harrington, D. and Murphy, M. (1992). Long distance transportation of steers to slaughter: effect of stocking density on physiology behaviour and carcass quality. *Livestock Production Science*, 30, 223-238.

Tatum, D. (1996). Beef grading. *United States Department of Agriculture: Standards for Grades of Slaughter Cattle and Standards for Grades of Carcass Beef.* Agricultural Marketing Services, USDA. Washington, D.C. USA. 98pp.

Taylor, R.G. (2003). Meat tenderness: theory and practice. *49th International Congress of Meat Science and Technology*. 56-66pp.

Therkildsen, M., Vestergaard, M., Busk, H., Jensen, M.T., Riis, B., Karlsson, A.H., Kristensen, L., Ertbjerg, P. and Oksberg, N. (2004). Compensatory growth in slaughter pigs-invitro muscle protein turnover at slaughter, circulating IGF-I, performance and carcass quality. *Livestock Production Science* 88: 63-75.

Tilley, J.M.A. and Terry, R.A. (1963). A two-stage technique for the in vitro digestion of forage crops. *Journal of British Grassland Society* 18:104-111.

Topps, J.H. and Oliver, J. (1993). Animal foods of central Africa, *Zimbabwe Agriculture Journal*. Technical Handbook. 2:17 – 44.

Trail, J.C.M., Buck, N.G., Light, D., Rennie, T.W., Rutherford, A., Miller, M., Pratchett, D. and Capper, B.S. (2010). Productivity of Africander, Tswana, Tuli and crossbred beef cattle in Botswana. [http://journals. cambridge. org/action/ display Abstract;jsessionid=F756AF80889C3AEA8E9D9F33E8D1EA81.tomcat1? From Page=online&aid=7355364] site visited on 10/10/2010.

URT (United Republic of Tanzania) (2005). *Basic Data for Agriculture Sector 1995/96 - 02002/2003*: Tanzania Mainland. 83pp.

Van Laack, R.L.J.M., Stevens, S.G. and Stalder, K.J. (2001). The influence of ultimate pH and intramuscular fat content on pork tenderness and tenderization. *Journal of Animal Science* 79: 392 – 397.

Van Laack, R.L. and Kauffman, R.G. (1999). Glycolytic potential of red, soft, exudative Pork longissimus muscle. *Journal of Animal Science* 77: 2971 – 2973.

Van Soest, P.J. (1994). Nutritional Ecology of the Ruminant. Cornell University Press. Ithaca and London, 476 pp.

Villarroel, M., María, G.A., Sañudo, C., Olleta, J.L. and Gebresenbet, G. (2003). Effect of transport time on sensorial aspects of beef meat quality. *Meat Science* 63 (3): 353-357.

Topps, J.H. and Oliver, J. (1993). Animal foods of central Africa, *Zimbabwe Agriculture Journal*. Technical Handbook. 2:17 – 44.

Trail, J.C.M., Buck, N.G., Light, D., Rennie, T.W., Rutherford, A., Miller, M., Pratchett, D. and Capper, B.S. (2010). Productivity of Africander, Tswana, Tuli and crossbred beef cattle in Botswana. [http://journals. cambridge. org/action/ display Abstract;jsessionid=F756AF80889C3AEA8E9D9F33E8D1EA81.tomcat1? From Page=online&aid=7355364] site visited on 10/10/2010.

URT (United Republic of Tanzania) (2005). *Basic Data for Agriculture Sector 1995/96 - 02002/2003*: Tanzania Mainland. 83pp.

Van Laack, R.L.J.M., Stevens, S.G. and Stalder, K.J. (2001). The influence of ultimate pH and intramuscular fat content on pork tenderness and tenderization. *Journal of Animal Science* 79: 392 – 397.

Van Laack, R.L. and Kauffman, R.G. (1999). Glycolytic potential of red, soft, exudative Pork longissimus muscle. *Journal of Animal Science* 77: 2971 – 2973.

Van Soest, P.J. (1994). Nutritional Ecology of the Ruminant. Cornell University Press. Ithaca and London, 476 pp.

Villarroel, M., María, G.A., Sañudo, C., Olleta, J.L. and Gebresenbet, G. (2003). Effect of transport time on sensorial aspects of beef meat quality. *Meat Science* 63 (3): 353-357.

Wagner, J. and Stanton, T.L. (2010). Formulating rations with Pearson's square. Colorado State University, US Department of Agriculture. Bull. 1: 618pp.

Wanatabe, A., Daly, C.C. and Devine, C.E. (1996). The effects of the ultimate pH of meat on tenderness changes during ageing. *Meat Science* 42: 67 – 78.

Warris, P.D. (2004). Meat quality. In: Meat science: *An Introductory text*. CABI Publishing. Bristol, UK. 310 pp.

Waritthitham, A., Lambertz, C., Langholz, J., Wickie, M. and Gauly, M. (2010). Muscle Fibre characteristics and their relationship to water holding capacity of Longissimus dorsi muscle in Brahman and Charolais crossbred bulls. *Asian-Australian Journal of Animal Sciences* 23(5): 665-671.

Webb, E.C. and O'Neill, H.A. (2008). The animal fat paradox and meat quality. *Meat Science* 80(1): 28-36.

Weisbjerg, M.R., Hvelplund, T., Madsen, J., Mtenga, L.A. and Mwilawa, A.J. (*In press*). Evaluation and Combination of feeds for improved beef production. In: *Proceedings of the 33rd TSAP Conference held* 29 November –1 December, 2007 at IACC, Arusha, Tanzania.

Wheeler, T.L., Savell, J.W., Cross, H.R., Lunt, D.K. and Smith, S.B. (1990a). Effect of post- mortem treatments on the tenderness of meat from Hereford, brahman and brahman-cross beef cattle. *Journal of Animal Science* 68: 3677-3686.

Wheeler, T.L., Savell, J.W., Cross, H.R., Lunt, D.K. and Smith, S.B. (1990b). Mechanisms Associated with the Variation in Tenderness of Meat from Brahman and Hereford Cattle. *Journal of Animal Science* 68: 4206-4220.

Wood, J.D., Enser, M., Fisher, A.V., Nute, G.R., Richardson, R.I. and Sheard, P.R. (1999). Manipulating meat quality and composition. Nutrition Society 58: 363–370.

Wulf, D.M., Emnett, R.S., Leheska, J.M. and Moeller, S.J. (2002). Relationships among glycolytic potential, dark cutting (dark, film and dry) beef, and cooked beef palatability. *Journal of Animal Science* 80: 1895 – 1903.

Yu, L.H., Lee, E.S., Jeong, Y.Y., Paik, H.D., Choi, J.H. and Kim, C.J. (2005). Effects of thawing temperature on the physicochemical properties of pre-rigor frozen chicken breast and leg muscles. *Meat Science* 71: 375 -382.

APPENDICES

Appendix 1: Schedule for slaughtering dates, carcass measurements, sampling of LD muscle and dissection of 6th rib joint in Expt. 1

Dates	Activity
27th March, 2008 Thursday	Rehearsal /Review of activity PROTOCOL
"" ""	Arrival of 20 animals from Kongwa at Kizota Abattoir for slaughtering – 1st lot (at 5.00pm)
28th March, 2008 FRIDAY	Slaughtering of 20 animals and Detailed measurement* taken *LUNCH -*
"" ""	Arrival of 40 animals from Kongwa at Kizota Abattoir for slaughtering – 2nd lot (at 5.20pm)
29th March, 2008 SATURDAY	Slaughtering of 40 animals and Non-Detailed measurement to be taken *LUNCH -*
"" ""	Measurements taken after 24 hrs of 1st Lot
30th March, 2008 Sunday	Measurements and Sampling after 48 hrs – carcass of lot 1 Note: to take sample on 7th April & 17th April for storage *Small Lunch -*
"" "	Arrival of 22 animals from Kongwa at Kizota Abattoir for slaughtering – 3rd lot (at 5.00pm)
31st March, 2008 MONDAY	Slaughtering of 22 animals and Detailed measurement taken *LUNCH -*
"" ""	Transportation of 60 carcasses for SALE
1st April, 2008 Tuesday	Measurements taken after 24 hrs – 3rd lot *Small Lunch*
2nd April, 2008 Wednesday	Measurements and Sampling after 48 hrs – 3rd Lot Note: to take sample on 11th April & 21st April for storage *Small Lunch*

* Detailed measurements = Recording of all the carcass, non-carcass measurements, temperature and pH readings at 45 minutes and 6 hours.

3rd April, 2008 Thursday	Arrival of 22 animals from Kongwa at Kizota Abattoir for slaughtering – 4th lot (at 5.00pm)
4th April, 2008 FRIDAY	Slaughtering of 22 animals and Detailed measurement taken
	LUNCH -
..'' ..''	Arrival of 16 animals from Kongwa at Kizota Abattoir for slaughtering – 5th lot (at 5.20pm)
5th April, 2008 Saturday	Slaughtering of 16 animals and Non-Detailed measurement to be taken
	LUNCH -
..'' ..''	Measurement taken after 24 hrs Lot 4
6th April, 2008 Sunday	Measurements and Sampling after 48 hrs – 4th lot Note: to take sample on 7th April & 17th April for storage
7th April, 2008 Monday	Transportation of 60 carcasses for SALE

* Detailed measurements = Recording of all the carcass, non-carcass measurements, temperature and pH readings at 45 minutes and 6 hours.

Appendix 2: Carcass classification according to EUROP classification system

Category of classification	Ranking no	Description of rank
A: Carcass conformation		
	15	E +
Exceptional muscle development	14	E
	13	E -
	12	U +
Very good muscle development	11	U
	10	U -
	9	R +
Good muscle Development	8	R
	7	R -
	6	O +
Average Muscle Development	5	O
	4	O -
	3	P +
Poor muscle Development	2	P
	1	P -
B: Carcass fat layer Classification		
None up to low fat cover	1	-
Slight fat cover	2	-
Smooth fat cover	3	-
Abundant fat cover	4	-
Thick fat cover	5	-
C: Carcass meat colour classification		
Extra light	1	-
Fairly light	2	-
Normal	3	-
A little dark/ Yellow	4	-
Dark/Yellow	5	-

Appendix 3: Determination of thawing and cooking loss, and meat toughness using Warner-Bratzler Shear Force (WBSF)

Three pieces of muscle LD stored for 2, 10 and 20 days kept in the freezer, were taken for analysis on WBSF as per the following procedures:

Day 1

1. Meat samples were removed from the freezer and then weighed frozen together with sealed plastic bags (W1) in order to determine the thawing loss.
2. The meat samples were placed in the refrigerator (+4°C) separately in one layer on a metal plate and thawed for 24 hours.

Day 2

1. The meat samples were taken from the refrigerator then the seal was opened, and the muscle juice inside was removed.
2. The meat samples together with the sealed plastic bags were weighed (W2).

*Thawing Loss (%) = [(weight before thaw (W1)-weight after thaw (W2))/W1]*100*

3. Meat samples were put in new plastic bags and sealed with vacuum pack machine
4. The vacuum sealed meat samples were weighed (W3) (for determination of cooking loss)
5. The vacuum packed meat samples (6 x 7 cm) were heat-treated at 75° C for 60 minutes in a circulating water bath. Here it was the internal temperature of the meat that had to be 75°C. The water bath was set at a slightly higher temperature of 78 °C above the required meat temperature. Metal rods from the lab were used to keep the meat samples down in the water so that every sample was covered with water and samples were kept separate from each other. For every heat treatment the temperature of the water bath and the internal temperature of the meat were checked with the thermometer stick. A thermometer stick was inserted in one of the sealed plastic bags from the top end and was pushed down to reach meat sample inside such that the meat sample did not get in direct contact with the water from the water bath after making a hole in the vacuum pack.
6. After one hour when the above cooking was over, heat treatment was stopped. The cooked samples were shifted in cold tap water for cooling. The tap water was left flowing on top of the container with samples for about two hours until the internal temperature of the meat had reached 24°C.

7. After cooling, the vacuum packs with meat samples were opened and the muscle juice inside were removed. Meat samples were wiped with a clean tissue paper and then weighed (W4) to assess cooking loss.

*Cooking loss = [(weight of raw steak after thawing (W3) – weight of cooked steak (W4))/ weight of raw steak after thawing (W3)] * 100*

8. Then the dimensions of the meat samples were adjusted with a knife so that all meat samples had identical dimensions, e.g. 5 x 6 cm in the fibre direction.
9. From each sample, small rectangular blocks were cut with a scalpel. The dimensions of these samples were exactly 1cm high x 1cm width x 5 cm length in the fibre direction. A minimum of 4 blocks were prepared per meat sample. Each block of 5 cm long were then sheared with the triangular shaped Warner-Bratzler blade three times. If the blocks were shorter it was not possible to cut three times and more blocks had to be prepared. From each meat sample, a minimum of 12 repetitions were performed. The sampled blocks had no tendons in between as they could affect the shearing.
10. Important note: (a) The suitable load cell were mounted on the food texture analyzer (for beef and lamb =1 kN) and the protocol for the machine used was followed. Warner-Bratzler shear blade, with a triangular slot cutting edge, attached to Zwick/Roell (Z2.5 German) instrument was used to determine the force (N) required to shear through a muscle cube at right angle to the muscle fibre direction.
11. Important note: Suitable software (*Text expert 8.1 Zwick Roell)* was used which allowed the recording and calculations specified. The following specifications in the program were used:
    - Compression.
    - Crosshead Speed: used 200.000 mm/min.
    - Sampling Rate: 20.000 pts/sec.
    - Specimens per screen: 12 (repetitions).
    - Load cell: used a 1 kN

Appendix 4: Schedule for slaughtering dates, carcass measurements, sampling of LD muscle and dissection of 6th rib joint in Expt. 2

Dates	Activity
26/12/2008 Friday	Rehearsal /Review of activity PROTOCOL (participation of all the players)
26/12/2008 Friday	Arrival of 24 animals from Kongwa at Kizota Abattoir for slaughtering – 1st lot (5.00 pm)
27/12/2008St	Slaughtering of 24 steers and detailed measurement* taken
"" ""	*- LUNCH -*
28/12/08 Sund	Measurements after 24 hrs
29/12/2008 Monday	Measurements and sampling after 48 hrs – carcass Note: to take sample on 6th Jan and 16th Jan for storage
"" ""	*- Small Lunch -*
"" ""	Arrival of 24 animals from Kongwa at Kizota Abattoir for slaughtering – 2nd lot (5.00 pm)
30/12/2008Tu	Slaughtering of 24 animals and detailed measurement taken
"" ""	*- LUNCH -*
31/12/08 Wed	Measurements after 24 hrs
01/01/2009 Thursday	Measurements and sampling after 48 hrs – carcass Note: to take sample on 10th Jan and 20th Jan for storage
"" ""	*- Small Lunch -*
"" ""	Arrival of 24 animals from Kongwa at Kizota Abattoir for slaughtering – 3rd lot (5.00 pm)
02/01/2009Frid	Slaughtering of 24 animals and detailed measurement
"" ""	*- LUNCH -*
03/01/09 Sat	Measurements after 24 hrs
04/01/2009 Sunday	Measurements and sampling after 48 hrs – carcass Note: to take sample on 13th Jan and 23rd Jan for storage
"" ""	*- Small Lunch -*
	Sales of Carcass

* Detailed measurements = Recording of all the carcass, non-carcass measurements, temperature and pH readings at 45 minutes and 6 hours.

Appendix 5: Forage botanical composition (%) in grazed paddocks in Expt. 1 (December 2007 to March, 2008)

Species	Frequency of occurrence	Percentage Composition	Perennial/ annual	Grass/legume /herb/Forbs
Aristida adscensionis	220	15.7	annual	grass
Dactyloctenium aegyptium	180	12.8	annual	grass
Cenchrus ciliaris	165	11.8	perennial	grass
Macrotyloma uniflorum	160	11.4	annual	legume
Urochloa trichopus	150	10.2	annual	grass
Tridax procumbens	70	5.0	annual	herb
Cynodon plectostachyus	40	2.9	perennial	grass
Chloris virgate	37	2.6	annual	grass
Watheria Americana	35	2.5	annual	herb
Tephrosia pumila	33	2.4	perennial	forbs
Leucas martinscensis	34	2.4	annual	herb
Brachiaria serifolia	30	2.1	annual	grass
Monechma sp.	26	1.9	annual	herb
Eragrostis patterns	25	1.8	annual	grass
Panicum spp	24	1.7	perennial	grass
Neurautanenia mitis	20	1.4	perennial	legume
Astipomoea hyoscamoides	17	1.2	annual	herb
Gutenbergia polycephala	17	1.2	annual	herb
Bidens lineribora	15	1.1	annual	herb
Crotalaria barkea	14	1.0	annual	legume
Digitaria velutina	14	1.0	annual	grass
Indigophera sp.	9	0.6	perennial	forb
Other various spp	75	5.3	various	various
Total	**1410**	**100.0**	-	-

Appendix 6: LSMeans for the main effects of breed and diet on growth performance and, hay and concentrate intake feed intake by cattle in Expt. 1

Parameter	Breed (B)				Dietary treatment (D)							B*D
	Boran	TSHZ	SEM	*P – Value*	Graz+C00	Graz+C50	Hay+C60	Hay+C80	Hay+C100	SEM	*P - Value*	
Number of animals	60	60	-	-	24	24	24	24	24	-	-	-
Feeding period, (days)	100	100	-	-	100	100	100	100	100	-	-	-
Animal weight (kg)												
Initial liveweight (ILW)	168^{a}	99^{b}	1.4	<.0001	133	134	131	136	134	1.13	0.6440	0.7420
Final liveweight (FLW)	241^{a}	162^{b}	1.2	<.0001	195^{cd}	206^{b}	186^{d}	203^{bc}	218^{a}	2.9	<.0001	0.7852
Liveweight gain	74	63	1.6	0.0672	62^{cd}	74^{b}	56^{d}	67^{bc}	83^{a}	2.6	<.0001	0.4361
ADG (g/day)	736^{a}	623^{b}	18.2	<.0001	624^{cd}	717^{b}	552^{d}	672^{bc}	833^{a}	28.9	<.0001	0.0242
Feed intake (kg/head/day)												
Number of animals	36	36	-	-	24	24	24	24	24	-	-	-
Hay Intake	1.9^{a}	1.6^{b}	0.02	<.0001	na	na	2.0^{a}	1.6^{ab}	1.4^{b}	0.02	<.0001	<.0001
Concentrate Intake	5.0^{a}	4.1^{b}	0.02	<.0001	na	na	3.6^{b}	4.6^{ab}	5.4^{a}	0.02	<.0001	<.0001
TDMI	6.9^{a}	5.7^{b}	0.02	<.0001	na	na	5.7^{b}	6.3^{ab}	6.8^{a}	0.09	<.0001	<.0001
ME Intake MJ/day)	78.3^{a}	64.4^{b}	0.2	<.0001	na	na	62^{c}	72^{b}	80^{a}	0.19	<.0001	<.0001
ME MJ/ kg gain	110^{a}	107^{b}	0.2	<.0001	na	na	117^{a}	112^{ab}	98^{b}	0.19	<.0001	<.0001
TDMI as % LW	2.9^{b}	3.5^{a}	0.1	<.0001	na	na	3.3^{a}	3.1^{b}	3.2^{ab}	0.06	0.0226	0.6223
FCR (kg feed/ kg gain)	9.8^{a}	8.9^{b}	0.2	0.0265	na	na	10.8^{a}	9.0^{b}	8.3^{c}	0.3	<.0001	0.4361

^{abc}LSMeans with different superscripts in the same row are significantly different ($P<0.05$). P-value = Probability values; Graz+C00 = grazing alone as control; Graz+C50 = grazing + 50 % *ad libitum* concentrate intake; Hay+C60, Hay+C80 and Hay+C100 = (*ad libitum* hay + 60, 80 and 100 % of the *ad libitum* concentrate intake respectively); SEM = Standard error of mean; TDMI = Total dry matter intake; FLW = Liveweight, ADG = Average daily gain; FCR = kg of feed/ kg of gain and na = Not applicable.

Appendix 7: LSMeans for the effects of breed and diet on individual treatments and their interactions on killing out characteristics, non carcass components and their proportions in Expt. 1

Breed	Boran					Tanzania shorthorn zebu						P - Value		
Treatment	Graz+C00	Graz+C 50	Hay+C60	Hay+C80	Hay+C100	Graz+C00	Graz+C50	Hay+C60	Hay+C80	Hay+C100	SEM	B	D	B*D
Weights (kg)														
Gut content	22 ^{a}	21 ^{a}	12 ^{b}	10 ^{b}	12 ^{b}	17 ^{a}	14 ^{b}	11 ^{b}	13 ^{b}	12 ^{b}	1.7	0.1197	<.0001	0.0287
Empty body wt.	215 ^{c}	227 ^{b}	212 ^{c}	235 ^{ab}	243 ^{a}	138 ^{f}	166 ^{d}	140 ^{e}	143 ^{e}	168 ^{d}	4.1	0.0001	<.0001	0.5467
Hot carcass wt.	120 ^{b}	128 ^{ab}	117 ^{b}	127 ^{b}	142 ^{a}	75 ^{cd}	84 ^{c}	70 ^{d}	78 ^{cd}	97 ^{c}	5.1	0.0001	<.0001	0.9918
Dressing (%)	50 ^{ab}	51 ^{ab}	52 ^{ab}	52 ^{ab}	56 ^{a}	48 ^{b}	49 ^{b}	46 ^{b}	51 ^{ab}	54 ^{a}	2.1	0.0257	0.0361	0.6790
Non carcass components (kg)														
Pluck	8.6 ^{ab}	9.1 ^{a}	7.9 ^{b}	8.6 ^{ab}	9.2 ^{a}	6.2 ^{c}	6.5 ^{c}	5.3 ^{c}	6.4 ^{c}	7.9 ^{b}	0.4	<.0001	0.0002	0.4212
Kidney	0.6 ^{ab}	0.6 ^{ab}	0.5 ^{ab}	0.6 ^{ab}	0.7 ^{a}	0.3 ^{c}	0.4 ^{bc}	0.3 ^{c}	0.4 ^{bc}	0.5 ^{ab}	0.2	<.0001	0.0209	0.4212
Mesenteric fat	3.5 ^{de}	4.5 ^{cd}	5.1 ^{bc}	5.2 ^{b}	7.1 ^{a}	2.4 ^{e}	3.1 ^{e}	3.4 ^{de}	3.9 ^{c}	5.9 ^{ab}	0.4	<.0001	<.0001	0.9440
Total fat	5.3 ^{c}	6.7 ^{bc}	7.4 ^{b}	8.0 ^{b}	10.2 ^{a}	3.6 ^{d}	4.5 ^{d}	5.0 ^{cd}	5.8 ^{c}	8.8 ^{a}	0.02	<.0001	<.0001	0.8947
Proportion Gut content														
% FLW	16 ^{bc}	16 ^{bc}	13 ^{cd}	12 ^{d}	12 ^{d}	20 ^{a}	18 ^{ab}	14 ^{c}	15 ^{bc}	14 ^{c}	1.0	0.0001	0.0001	0.1511
% ELW	18 ^{a}	17 ^{ab}	14 ^{b}	13 ^{b}	13 ^{b}	22 ^{a}	19 ^{a}	20 ^{a}	18 ^{a}	15 ^{b}	1.3	0.0001	0.0008	0.1547

[abcde] LSMeans with different superscripts in the same row are significantly different ($P<0.05$). P-value = Probability values; Graz+C00 = grazing alone as control; Graz+C50= grazing + 50 % *ad libitum* concentrate intake; Hay+C60, Hay+C80 and Hay+C100 = (*ad libitum* hay + 60, 80 and 100 % of the *ad libitum* concentrate intake respectively); Standard error of mean (SEM); B = Breed; D = Diet; B*D = Interaction effect; Final Liveweight (FLW) and Empty Liveweight (ELW). Total fat = fat from trimmed small intestines, pluck and kidney

Appendix 8: LSMeans for the effects of breed and diet on carcass linear measurements and EUROP carcass classification on the individual treatment in Expt. 1

Parameter	Boran					Tanzania shorthorn zebu						P - Value		
	Graz+C00	Graz+C50	Hay+C60	Hay+C80	Hay+C100	Graz +C00	Graz+C50	Hay+C60	Hay+C80	Hay+C100	SEM	B	D	B*D
Carcass measurements (cm)														
Carcass length	106^{a}	107^{a}	100^{a}	104^{a}	106^{a}	96^{b}	99^{b}	94^{b}	95^{b}	99^{ab}	3.7	0.0001	0.5039	0.9881
Chest depth	56^{ab}	57^{a}	54^{ab}	56^{a}	59^{a}	48^{c}	50^{bc}	47^{c}	50^{b}	55^{ab}	2.2	0.0001	0.0489	0.9350
Limb Circ.	68^{a}	68^{a}	66^{a}	68^{a}	70^{a}	54^{c}	55^{bc}	53^{c}	56^{bc}	64^{ab}	3.1	0.0001	0.1096	0.5219
Fat thickness	2.5^{c}	2.6^{c}	2.8^{bc}	3.3^{ab}	4.1^{a}	2.1^{c}	2.2^{c}	2.1^{c}	2.6^{a}	3.1^{b}	0.3	0.1490	0.0001	0.7621
Back fat	0.9^{b}	1.0^{b}	0.9^{b}	1.1^{b}	1.3^{ab}	0.7^{b}	0.9^{b}	0.9^{b}	1.0^{b}	1.5^{b}	0.1	0.3334	0.0001	0.3470
LD Area (cm^2)	33^{b}	39^{bc}	27^{b}	-	56^{a}	25^{c}	38^{bc}	20^{d}	-	43^{ab}	5.9	0.0975	0.0004	0.7880
Carcass EUROP Classification														
Conformation	8.1^{c}	8.3^{bc}	8.5^{b}	8.5^{b}	9.6^{a}	6.2^{e}	6.7^{de}	6.8^{de}	7.2^{cd}	7.7^{bc}	0.2	0.0001	0.0001	0.6757
Fatness	3.2	3.5	3.8	3.9	4.1	2.8	3.1	3.3	3.7	3.8	0.2	0.1490	0.0001	0.9817
Meat colour	4.3^{a}	4^{a}	3.2^{b}	2.9^{b}	3.0^{b}	4.5^{a}	4.1^{a}	3.1^{b}	3^{b}	2.9^{b}	0.2	0.3334	0.0001	0.6246

[abc] LSMeans with different superscripts in the same row are significantly different ($P<0.05$). *P*-value = Probability values; Graz+C00 =grazing alone as control; Graz+C50= grazing + 50 % *ad libitum* concentrate intake; Hay+C60, Hay+C80 and Hay+C100 = (*ad libitum* hay + 60, 80 and 100 % of the *ad libitum* concentrate intake respectively); Standard error of mean (SEM); B = Breed; D = Diet; B*D = Interaction effect; Limb circumference (Circ.); LD = Longissimus dorsi; Carcass conformation score (1-15); Carcass fatness score (1-5) and Carcass meat colour score (1-5).

Appendix 9: LSMeans of the effects of breed and diet on carcass physical composition of individual treatments in Expt. 1

Parameter	Boran				Tanzania shorthorn zebu					*P - Value*		
	Graz+C00	Graz+C50	Hay+C60	Hay+C100	Graz+C00	Graz+C50	Hay+C60	Hay+C100	SEM	B	D	B*D
Carcass Composition (kg) 6th Rib												
Rib weight	3.0^{b}	3.0^{a}	2.7^{ab}	2.5^{b}	3.2^{b}	3.1^{a}	3.4^{b}	3.1^{a}	0.1	0.0001	0.2001	0.9163
Lean	2.0^{ab}	2.0^{ab}	1.7^{b}	1.5^{ab}	2.4^{b}	2.1^{ab}	2.3^{b}	2.1^{a}	0.1	0.0001	0.2443	0.7268
Fat	0.5^{a}	0.5^{a}	0.5^{a}	0.6^{a}	0.3^{b}	0.5^{a}	0.6^{a}	0.6^{a}	0.03	0.0001	0.0039	0.6284
Bone	0.5^{ab}	0.5^{ab}	0.5^{ab}	0.4^{ab}	0.5^{ab}	0.5^{ab}	0.6^{ab}	0.4^{ab}	0.02	0.0001	0.2190	0.7219
% Carcass composition 6th Rib												
Lean	67^{b}	68^{b}	63^{ab}	61^{ab}	75^{a}	69^{a}	67^{b}	67^{b}	1.6	0.0110	0.1675	0.4995
Fat	17	16	19	22	8	15	17	20	1.3	0.0152	0.0001	0.2083
Bone	17	16	19	17	17	15	17	13	1.1	0.3451	0.0912	0.7113
Ratios of 6th Rib components												
Lean:fat	4.0^{b}	4.3^{b}	3.3^{bc}	2.8^{c}	9.0^{a}	4.5^{b}	4.0^{b}	3.3^{c}	0.4	0.0037	0.0006	0.1249
Lean:bone	4.0	4.3	3.3	3.7	4.5	4.5	4.0	5.0	1.7	0.2293	0.5508	0.5492
Fat:Bone	1.0	1.0	1.0	1.3	0.5	1.0	1.0	1.5	0.3	0.6015	0.2903	0.3330

^{abc} LSMeans with different superscripts in the same row are significantly different (P<0.05). P-value = Probability values; Standard error of mean (SEM); Graz+C00 =grazing alone as control; Graz+C50= grazing + 50 % *ad libitum* concentrate intake; Hay+C60 and Hay+C100 = (*ad libitum* hay + 60 and 100 % of the *ad libitum* concentrate intake respectively); Standard error of mean (SEM); B = Breed; D = Diet; B*D = Interaction effect;

Appendix 10: LSMeans of the effects of breed and diet on temperature decline of *Longissimus dorsi* (LD) of carcasses in Expt. 1

Breed	Diets	45 minutes	6 h	24 h	48 h	Tdrop 1	Tdrop 2
		Temperature (^{o}C) readings					
	Graz+C00	38.9^{ab}	26.6^{b}	3.5^{b}	2.0	12.3^{a}	23.1^{b}
Boran	Graz+C50	39.6^{ab}	26.9^{ab}	3.6^{ab}	2.3	12.9^{a}	23.3^{ab}
	Hay+C60	40.0^{a}	27.4^{a}	4.1^{a}	2.1	12.4^{a}	23.0^{a}
	Hay+C100	40.1^{a}	27.8^{a}	4.3^{a}	2.5	12.3^{a}	23.5^{a}
	Graz+C00	37^{c}	25.8^{c}	3.1^{b}	2.1	11.9^{a}	21.4^{c}
TSHZ	Graz+C50	37.8^{c}	26.3^{b}	3.0^{b}	2.3	11.8^{a}	22.9^{b}
	Hay+C60	38.4^{bc}	26.3^{b}	3.1^{b}	2.5	12.5^{a}	23.5^{a}
	Hay+C100	38.9^{ab}	28.9^{ab}	$4..0^{a}$	2.5	10.8^{b}	23.2^{ab}
	SEM	0.5	0.3	0.2	0.2	0.5	0.3
	B	<.0001	<.0002	<.0008	0.2586	0.0133	<.0001
P-value	D	0.0920	<.0048	<.0030	0.1156	0.0385	<.0001
	B*D	0.6820	0.8787	0.2722	0.2827	0.9668	0.3522

^{abcd} LSMeans with different superscripts in the same column are significantly different (P<0.05). P-value = Probability values; Graz+C00 =grazing alone as control; Graz+C50= grazing + 50 % *ad libitum* concentrate intake; Hay+C60 and Hay+C100 = (*ad libitum* hay + 60 and 100 % of the *ad libitum* concentrate intake respectively); Standard error of mean (SEM); Tdrop 1 = Temperature drop from 45 min to 6hrs; Tdrop 2 = Temperature drop from 6hrs to 24hrs; B = Breed; D = Diet: B*D = Interaction effect

Appendix 11: LSMeans of the effects of breed and diet on pH changes of *Longissimus dorsi* (LD) of carcasses in Expt. 1

		pH readings					
Breed	**Diets**	**45 minutes**	**6 h**	**24 h**	**48 h**	**pHchange1**	**pHchange2**
	Graz+C00	6.36	5.80^{ab}	5.72	5.67	0.56	0.08
Boran	Graz+C50	6.33	5.77^{bc}	5.71	5.67	0.56	0.07
	Hay+C60	6.26	5.76^{cd}	5.74	5.70	0.5	0.02
	Hay+C100	6.24	5.74^{d}	5.72	5.71	0.52	0.02
	Graz+C00	6.37	5.83^{a}	5.7	5.61	0.5	0.13
TSHZ	Graz+C50	6.34	5.78^{bc}	5.70	5.64	0.54	0.08
	Hay+C60	6.31	5.75^{cd}	5.69	5.60	0.53	0.07
	Hay+C100	6.28	5.73^{d}	5.67	5.62	0.55	0.06
	SEM	0.10	0.10	0.10	0.03	0.18	0.18
	B	0.9088	0.0718	0.7255	0.0037	0.0439	0.5294
P-value	D	0.5522	0.0146	0.5531	0.9062	0.0036	0.1111
	B*D	0.5177	0.0317	0.5917	0.7069	0.1738	0.1118

^{abcd} LSMeans with different superscripts in the same column are significantly different (P<0.05). P-value = Probability values: Graz+C00 = grazing alone as control; Graz+C50 = Graz+C00 + 50 % *ad libitum* concentrate intake; Hay+C60 = *ad libitum* hay + 60% of the *ad libitum* concentrate intake; Hay+C100 = *ad libitum* hay + *ad libitum* concentrate intake; Standard error of mean (SEM): pHchange1 = pH change from 45 min to 6hrs; pHchange2 = pH change from 6hrs to 24hrs; B = Breed; D = Diet; B*D = Interaction effect

Appendix 12: LSMeans of the effects of breed and diet on percentage drip, thawing, cooking losses and shear force of LD of carcasses in Expt. 1

		Meat quality attributes			
Breed	**Diets**	**Drip loss (%)**	**Thawing loss (%)**	**Cooking loss (%)**	**Shear force (N)**
	Graz+C00	5.5	5.0	25.2	58[ab]
Boran	Graz+C50	4.0	4.7	24.8	45[d]
	Hay+C60	3.6	4.3	25.0	45[d]
	Hay+C100	3.1	4.1	23.0	42[d]
	Graz+C00	*5.9*	*5.2*	*27.7*	*62[a]*
TSHZ	Graz+C50	4.6	5.0	26.8	57[b]
	Hay+C60	3.5	4.4	27.6	48[cd]
	Hay+C100	2.4	4.1	26.1	42[d]
SEM		0.7	0.3	1.0	2.9
	B	0.9088	0.4431	0.0006	0.0386
P-value	D	0.0003	0.0392	0.2363	<.0001
	B*D	0.7701	0.9810	0.9608	0.1667

[abc] LSMeans with different superscripts in the same column are significantly different (P<0.05). P-value = Probability values: Graz+C00 = grazing alone as control; Graz+C50 = Graz+C00 + 50 % *ad libitum* concentrate intake; Hay+C60 = *ad libitum* hay + 60% of the *ad libitum* concentrate intake; Hay+C100 = *ad libitum* hay + *ad libitum* concentrate intake; Standard error of mean (SEM); B = Breed; D = Diet; B*D = Interaction effect

Appendix 13: LSMeans of the effects of breed and ageing time (days) on percentage thawing loss and cooking loss of muscle LD of carcasses in Expt. 1

Breed	Ageing time (days)	Meat quality attributes Thawing loss (%)	Cooking loss (%)	Shear force (N)
	2	5.5[a]	25.8	59.6[b]
Boran	10	5.0[a]	24.5	47.2[c]
	20	3.0[b]	23.1	35.7[d]
	2	6.0[a]	27.5	67.3[a]
TSHZ	10	5.2[a]	27.3	50.2[c]
	20	2.9[b]	27.1	38.9[d]
	SEM	0.3	0.8	2.1
	B	0.4431	0.0006	0.0386
P-value	A	<.0001	0.0666	<.0001
	B*A	0.5733	0.2609	0.5671

[abc] LSMeans with different superscripts in the same column are significantly different (P<0.05). P-value = Probability values: Graz+C00 = grazing alone as control: Graz+C50 = Graz+C00 + 50 % *ad libitum* concentrate intake; Hay+C60 = *ad libitum* hay + 60% of the *ad libitum* concentrate intake; Hay+C100 = *ad libitum* hay + *ad libitum* concentrate intake; Standard error of mean (SEM); B = Breed; A = Ageing time (days); B*A = Interaction

Appendix 14: LSMeans of the effects of diet and ageing time (days) on percentage thawing loss, cooking loss and shear force (N) on LD muscle in Expt. 1

Ageing time	Diet	Meat quality attributes		
		Thawing loss (%)	Cooking loss (%)	Shear force (N)
	Graz+C00	6.8^{a}	27.7	77.5^{a}
	Graz+C50	6.9^{a}	26.4	67.5^{a}
2 days	Hay+C60	5.3^{cb}	26.4	56.8^{b}
	Hay+C100	4.2^{d}	26.1	50.2^{c}
	Graz+C00	6.1^{ab}	25.0	62^{ab}
	Graz+C50	4.6^{d}	27.4	47.1^{cd}
10 days	Hay+C60	4.5^{d}	26.5	44de
	Hay+C100	5.1^{c}	24.7	42^{e}
	Graz+C00	2.3^{f}	26.7	41^{e}
	Graz+C50	3.1^{e}	23.7	38^{ef}
20 days	Hay+C60	3.3^{e}	27.1	37^{f}
	Hay+C100	3.1^{e}	23.0	34^{f}
	SEM	0.4	1.1	3.0
	A	<.0001	0.9608	<.0001
P-value				
	D	0.0392	0.2363	<.0001
	A*D	<.0001	0.2609	0.0072

^{abcdef}LSMeans with different superscripts in the same column are significantly different (P<0.05). P-value = Probability values; Graz+C00 = grazing alone as control; Graz+C50 = Graz+C00 + 50 % *ad libitum* concentrate intake; Hay+C60 = *ad libitum* hay + 60% of the *ad libitum* concentrate intake; Hay+C100 = *ad libitum* hay + *ad libitum* concentrate intake; Standard error of mean (SEM); D = Diet; A = Ageing time (days); D*A = Interaction effect

Appendix 15: Overall inputs and costs used during Expt. 1

ITEM/inputs	Quantity	Unit price (Tshs)	Amount (Tshs)
Animals costs	120	156,500	18,780,000.00
Feed costs			
Type of feeds	Amount (kilogram)		
Maize	15962	298	4,751,360.00
CSC	3899	109	423,750.00
Molasses	13870	205	2,850,000.00
Mineral mix	612	1750	2,052,473.68
Salt	774	250	370,825.08
Urea	150	940	270,213.62
Mineral blocks	192	1900	699,105.88
Cut hay	12360	120	1,489,000.00
Grazed forage	14400	100	1,440,000.00
	Sub total		14,346,728.27
3.0 Labour (wages) for 90 d			2,337,679.80
4.0 Veterinary drugs and services			700,000.00
5.0 Transport costs animals – market & abattoir			2,400,000.00
6.0 Fixed cost due to feedlot structure and feed store			1,245,000.00
TOTAL COSTS			**39,809,408.07**

Note: 1.00 USD is equivalent to 1,310 Tanzania shillings (Tshs) as per 20th Nov.2009

Appendix 16: Amount of feed used (kilogram as fed and kilogram DM) and the costs of feed used for 100 days for treatment in Expt. 1

	Breed			Boran					TSHZ				
	Finishing Diets			Graz+C00	Graz+C50	Hay+C60	Hay+C80	Hay+C100	Graz+C00	Graz+C50	Hay+C60	Hay+C80	Hay+C100
1.1	Total amount of feed used for 100 days for individual treatment												
		Kg as fed	*kg DMI*										
	Maize	18560	15962	0	1334	2174	2471	2965	0	939	1532	2076	2471
	CSC	4238	3899	0	326	531	603	724	0	229	374	507	603
	Molasses	19000	13870	0	732	1193	1356	1627	0	515	841	1139	1356
	Mix	612	-	0	51	83	95	114	0	36	59	80	95
	Slat	774	-	0	65	105	120	144	0	46	74	101	120
	Urea	150	-	0	13	20	23	28	0	9	14	20	23
	Blocks	192	-	0	16	26	30	36	0	11	18	25	30
	Hay	14890	12360	0	0	2713	2343	1850	0	0	2466	1726	1603
	Grazing	30000	14400	3600	3600	0	0	0	3600	3600	0	0	0
1.2	Total cost price of feed per treatment												
	Feed ;	*Total Kilo DM*	*Unit price Tshs.*										
	Maize	15962	298	0	397173	647244	735505	882606	0	279492	456013	617824	735505
	CSC	3899	109	0	35422	57724	65596	78715	0	24926	40670	55101	65596
	Molasses	13870	205	0	150464	245201	278638	334365	0	105882	172755	234056	278638
	Mix	-	1750	0	89526	145895	165789	198947	0	63000	102789	139263	165789
	Slat	-	250	0	16175	26359	29954	35944	0	11382	18571	25161	29954
	Urea	-	940	0	11786	19207	21827	26192	0	8294	13533	18334	21827
	Blocks	-	1900	0	30494	49694	56471	67765	0	21459	35012	47435	56471
	Hay	12360	120	0	0	326796	282233	222816	0	0	297087	207961	193107
	Grazing	14400	100	360000	360000	0	0	0	360000	360000	0	0	0
	Total costs of feed per diet per breed			360000	1091040	1518121	1636012	1847350	360000	874436	1136430	1345135	1546885
1.3	Total costs of feed per steer			30000	90920	126510	136334	153946	30000	72870	94703	112095	128907

Note. 1.00 USD is equivalent to 1,310/- Tanzania shillings as per 20th Nov 2009

Graz+C00 = grazing with no concentrate as control; Graz+C50 = Graz+C00 + 50 % *ad libitum* concentrate intake, Hay+C60 = *ad libitum* hay + 60% of the *ad libitum* concentrate intake, Hay+C80 = *ad libitum* hay + 80% of the *ad libitum* concentrate intake and Hay+C100 = *ad libitum* hay + *ad libitum* concentrate intake

Appendix 17: Total costs (input costs and fixed costs) per steer for individual treatment in Expt. 1

Breed	Boran					Tanzania shorthorn zebu				
Finishing Diets	**Graz+C00**	**Graz+C50**	**Hay+C60**	**Hay+C80**	**Hay+C100**	**Graz+C00**	**Graz+C50**	**Hay+C60**	**Hay+C80**	**Hay+C100**
Cost of animals	2376000	2376000	2376000	2376000	2376000	1380000	1380000	1380000	1380000	1380000
Costs of feed	360000	1091040	1518121	1636012	1847350	360000	874436	1136430	1345135	1546885
Cost of Labour (wages)	151949	198703	272729	272729	272729	151949	198703	272729	272729	272729
Veterinary drugs and services	70,000	70,000	70,000	70,000	70,000	70,000	70,000	70,000	70,000	70,000
Transportation	240000	240000	240000	240000	240000	240000	240000	240000	240000	240000
Total variable costs (TVC)	3197949	3975743	4476851	4594741	4806079	2201949	2763139	3099159	3307865	3509615
Fixed costs (FC) due-Feedlot	0	155625	155625	155625	155625	0	155625	155625	155625	155625
Total costs (TC)	3197949	4131368	4632476	4750366	4961704	2201949	2918764	3254784	3463490	3665240
TOTAL costs per steer	266496	344281	386040	395864	413475	183496	243230	271232	288624	305437

Note: USD 1 was equivalent to TSH 1,310 as per 20th Feb .2010; Graz+C00 = grazing with no concentrate as control; Graz+C50 = Graz+C00 + 50 % *ad libitum* concentrate intake; Hay+C60 = *ad libitum* hay + 60% of the *ad libitum* concentrate intake; Hay+C80 = *ad libitum* hay + 80% of the *ad libitum* concentrate intake and Hay+C100 = *ad libitum* hay + *ad libitum* concentrate intake.

Appendix 18: Estimated unit cost of production with fixed costs and without fixed costs per kg carcass for individual treatment in Expt. 1

Breed	Diets	Total costs	TVC	ASW	ADP	AHCW	PC/treat	UC-FC/kg carcass	UC-VC/kg carcass
	Graz+C00	3197949	3197949	237	0.5	120	1440	2221	2221
	Graz+C50	4131368	3975743	244	0.51	128	1536	2690	2588
Boran	Hay+C60	4632476	4476851	227	0.53	117	1404	3299	3189
	Hay+C80	4750366	4594741	240	0.52	127	1524	3117	3015
	Hay+C100	4961704	4806079	258	0.56	142	1704	2912	2820
	Graz+C00	2201949	2201949	154	0.48	75	900	2447	2447
	Graz+C50	2918764	2763139	164	0.48	84	1008	2896	2741
TSHZ	Hay+C60	3254784	3099159	149	0.46	70	840	3875	3689
	Hay+C80	3463490	3307865	167	0.52	78	936	3700	3534
	Hay+C100	3665240	3509615	171	0.54	97	1164	3149	3015

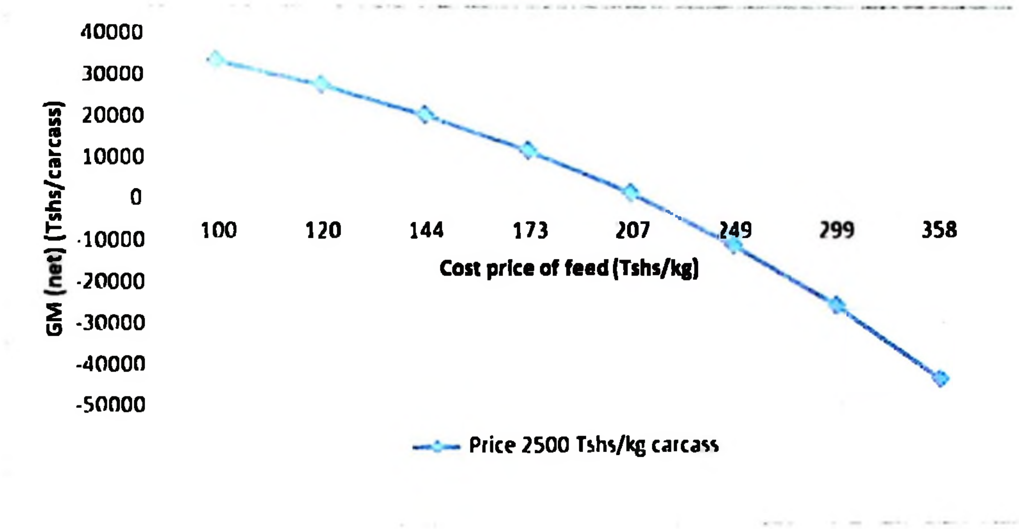
Note: 1.00 USD is equivalent to 1,310/= Tanzania shillings as per 20th Feb .2010; TVC=Total variable costs; ASW =Average slaughter weight; ADP = Average dressing percentage; AHCW =Average hot carcass weight; PC =Carcass produced (kg); UC = Unit cost; FC = fixed costs; VC = variable costs; Graz+C00 = grazing with no concentrate as control; Graz+C50 = Graz+C00 + 50 % *ad libitum* concentrate intake; Hay+C60 = *ad libitum* hay + 60% of the *ad libitum* concentrate intake; Hay+C80 = *ad libitum* hay + 80% of the *ad libitum* concentrate intake and Hay+C100 = *ad libitum* hay + *ad libitum* concentrate intake.

Appendix 19: Net returns (NRs) and Gross margin (GM) per animals for individual treatments in Expt. 1

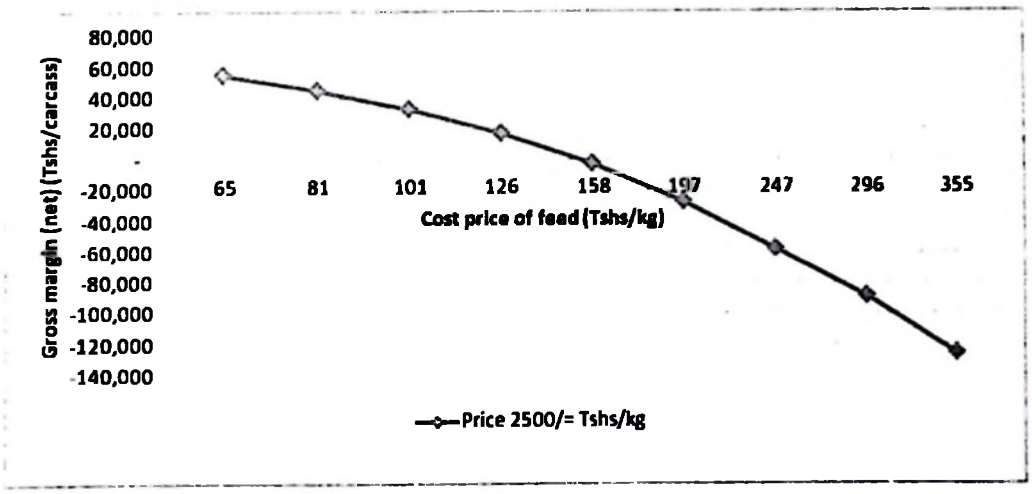
Breed				Boran					TSHZ				
Finishing Diets				Graz+C00	Graz+C50	Hay+C60	Hay+C80	Hay+C100	Graz+C00	Graz+C50	Hay+C60	Hay+C80	Hay+C100
Av. hot carcass weight (kilogram)				120	128	117	127	142	75	84	70	78	97
Unit cost with FC/kilogram carcass				2221	2690	3299	3117	2912	2447	2896	3875	3700	3149
Unit variable cost /kilogram carcass				2221	2588	3189	3015	2820	2447	2741	3689	3534	3015
Total production costs per steer				266496	344281	386040	395864	413475	183496	243230	271232	288624	305437
Total variable costs per steer				266496	331312	373071	382895	400507	183496	230262	258263	275655	292468
Sensitivity	anaysis	Sale Price Tshs/kilogram											
Case 1	TR	Price	2500	300000	320000	292500	317500	355000	187500	210000	175000	195000	242500
	NRs (Tshs/carcass)			33504	-24281	-93540	-78364	-58475	4004	-33230	-96232	-93624	-62937
	GM			33504	-11312	-80571	-65395	-45507	4004	-20262	-83263	-80655	-49968
Case 2	TR	Assume	3500	-	448000	409500	444500	497000	-	294000	245000	273000	339500
	NRs (Tshs/carcass)			-	103719	23460	48636	83525	-	50770	-26232	-15624	34063
	GM (Tshs/carcass)			-	116688	36429	61605	96493	-	63738	-13263	-2655	47032
Case 3	TR	Assume	5500	-	704000	643500	698500	781000	-	462000	385000	429000	533500
	NRs (Tshs/carcass)			-	359719	257460	302636	367525	-	218770	113768	140376	228063
	GM (Tshs/carcass			-	372688	270429	315605	380493	-	231738	126737	153345	241032
Case 4	TR	Assume	7000	-	896000	819000	889000	994000	-	588000	490000	546000	679000
	NRs (Tshs/carcass)			-	551719	432960	493136	580525	-	344770	218768	257376	373563
	GM (Tshs/ carcass)			-	564688	445929	506105	593493	-	357738	231737	270345	386532

Note: 1.00 USD is equivalent to 1,310 Tanzania shillings (TSH) as per 20th Feb .2010; Graz+C00 = grazing with no concentrate as control; Graz+C50 = Graz+C00 + 50 % *ad libitum* concentrate intake; Hyc60 = *ad libitum* hay + 60% of the *ad libitum* concentrate intake; Hyc80 = *ad libitum* hay + 80% of the *ad libitum* concentrate intake and Hyc100 = *ad libitum* hay + *ad libitum* concentrate intake; TR = Total revenue; NRs = Net Returns; GM = Gross margin

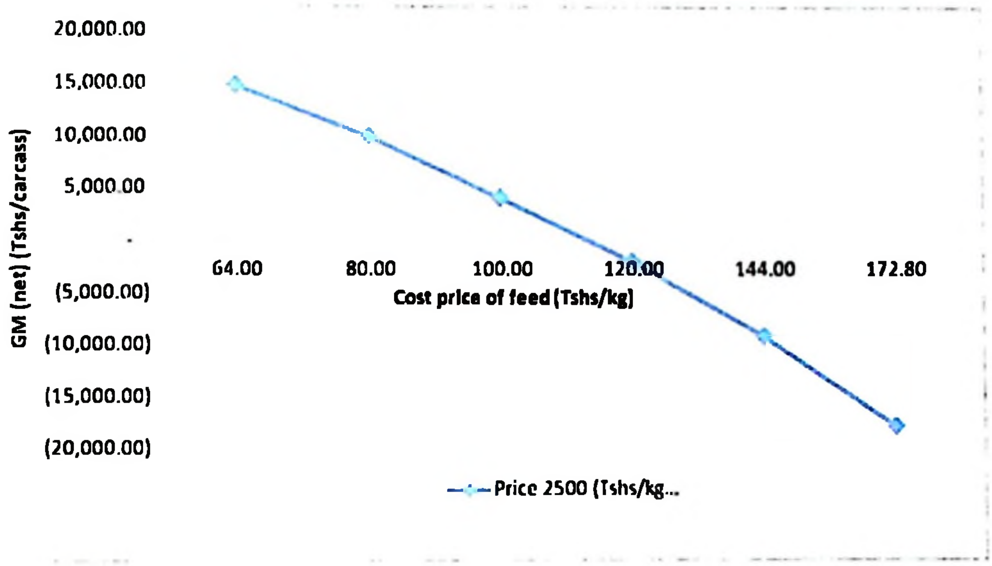
Appendix 20: The influence of cost of feed (Tshs/kg) on net returns for Boran finished on grazing alone (Graz+C00) when the carcass was sold at market price of Tshs 2500 per kg of carcass in Expt. 1



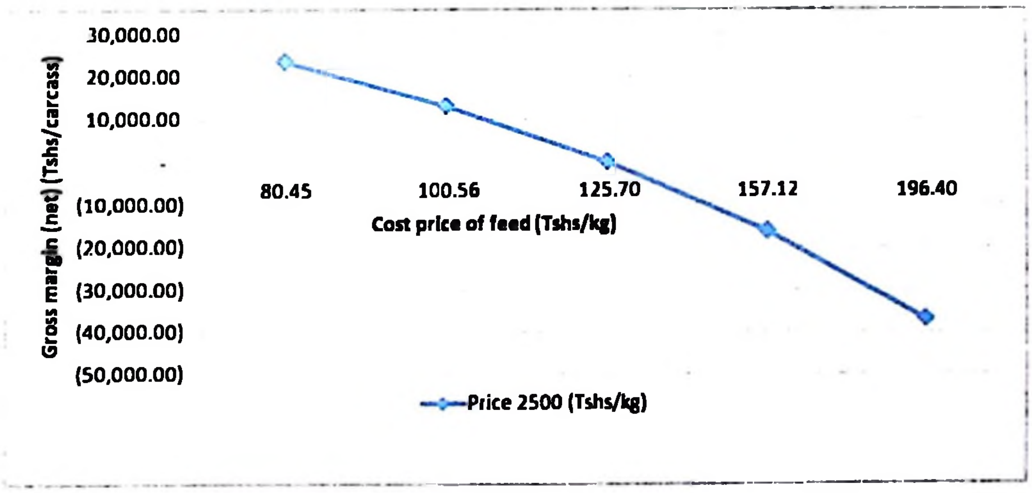
Appendix 21: The influence of cost of feed (Tshs/kg) on the net margins for Boran finished on *ad libitum* concentrate intake (Hay+C100) when carcass was sold at Tshs 2500 per kg of carcass in Expt. 1



Appendix 22: The influence of cost of feed (Tshs/kg) on the net returns for Tanzania shorthorn zebu finished on grazing (Graz+C00) when the carcass was sold at Tsh 2500 per kg of carcass in Expt. 1.



Appendix 23: The influence of cost of feed (Tshs/kg) on the net returns for Tanzania shorthorn zebu finished on *ad libitum* hay and *ad libitum* concentrate (Hay+C100) when the carcass was sold at Tshs 2500 per kg in Expt. 1



Appendix 24: Forage botanical composition (%) in grazed paddocks in Expt. 2 (August to November 2008)

Species	Frequency of occurrence	Percentage Composition	Perennial/ annual	Grass/legume /herb/Forbs
Aristida adscensionis	150	19.8	annual	grass
Cenchrus ciliaris	110	14.5	perennial	grass
Tridax procumbens	98	12.9	annual	herb
Watheria Americana	50	6.6	annual	herb
Leucas martinscensis	35	4.6	annual	herb
Tephrosia pumila	35	4.6	perennial	forbs
Cynodon plectostachyus	30	4.0	perennial	grass
Monechma sp.	30	4.0	annual	herb
Chloris virgate	25	3.3	annual	grass
Eragrostis patterns	22	2.9	annual	grass
Digitaria velutina	20	2.6	annual	grass
Neurautanenia mitis	20	2.6	perennial	legume
Urochloa trichopus	20	2.6	annual	grass
Indigophera sp	9	1.2	perennial	forbs
Bidens lineribora	5	0.7	annual	herb
Brachiaria serifolia	5	0.7	annual	grass
Crotalaria barkea	5	0.7	annual	legume
Macrotyloma uniflorum	5	0.7	annual	legume
Panicum spp	5	0.7	perennial	grass
Other various spp	68	9.0	various	various
Total	759	100.0	-	-

Appendix 25: LSMeans of the treatments and their interaction on growth performance and feed intake in Expt. 2

Parameter	Boran			Tanzania shorthorn zebu				*P - Value*		
	Graz+C00	Graz+C50	Hay+C100	Graz+C00	Graz+C50	Hay+C100	SEM	B	D	B*D
No. of animals	12	12	12	12	12	12	-	-	-	-
Feeding, day	90	90	90	90	90	90	-	-	-	-
Initial LW (kg)	217	210	213	171	169	169	3.9	<.0001	0.4938	0.7858
Final LW (kg)	214 ^{c}	254^{b}	309 ^{a}	167^{d}	202^{c}	257^{b}	4.7	<.0001	0.0001	0.7832
Weight gain (kg)	-7^{c}	33^{b}	66 ^{a}	0^{c}	34^{b}	63 ^{a}	3.8	0.6180	<.0001	<.0001
ADG (g/day)	-70^{c}	392^{b}	769 ^{a}	-19^{c}	363^{b}	702 ^{a}	28.3	0.5132	0.0001	0.1180
Hay (kg /head/day)	-	-	2.4	-	-	2.1	-	-	-	-
Conc.(kg /head/day)	-	3.3	6.4	-	3.0	6.4	-	-	-	-
TDMI (kg /head/day)	-	-	8.3	-	-	8.5	-	-	-	-
ME MJ/ kg gain	-	-	137	-	-	137	-	-	-	-
DMI as % LW	-		2.9	-	-	3.3	-	-	-	-
FCR (kg feed/ kg gain)	-	-	11.5	-	-	12.1	-	-	-	-

[abcd] LSMeans with different superscripts in the same row are significantly different ($P<0.05$). *P*-value =Probability values; Graz+C00 =grazing alone as control; Graz+C50= grazing + 50 % *ad libitum* concentrate intake; Hay+C100 = (*ad libitum* hay + *ad libitum* concentrate intake); Standard error of mean (SEM); B = Breed; D = Diet; B*D = Interaction effect; LW = Bodyweight; ADG = Average daily gain; TDMI = Total dry matter intake; DMI = Dry matter intake and FCR = Feed conversion ratio

Appendix 26: LSMeans for the effect of breed and diet on killing out characteristics and non carcass components for the individual treatments in Expt. 2

Parameter	Boran			Tanzania shorthorn zebu			SEM	P - Value		
	Graz+C00	Graz+C50	Hay+C100	Graz+C00	Graz+C50	Hay+C100		B	D	B*D
Weights (kg)										
Empty body weight.	199^{c}	232^{b}	294^{a}	149^{d}	185^{c}	243^{b}	8.7	<.0001	<.0001	0.9230
Hot carcass weight	111	125	160	81	103	139	0.5	<.0001	<.0001	0.5081
Dressing percentage (%)	46^{c}	51^{ab}	55^{a}	48^{bc}	51^{ab}	54^{a}	1.6	0.6366	<.0001	0.6662
Non carcass components (kg)										
Gut content	18	16	15	18	16	14	1.3	0.7797	0.0397	0.7542
Pluck	9.8	11.9^{c}	14.9^{a}	8.5	10.2	13.6^{b}	0.4	<.0001	<.0001	0.8756
Kidney	0.5	0.6	0.6	0.5	0.5	0.6	0.03	0.4160	0.0016	0.3249
Mesenteric fat	2.0^{c}	4.0^{b}	8.3^{a}	1.3^{c}	3.3^{bc}	7.4^{a}	0.4	0.0306	<.0001	0.9631
Total fat	2.6^{c}	5.3^{b}	11.3^{a}	1.9^{c}	4.4^{b}	10.4^{a}	0.5	0.0462	<.0001	0.9791
Proportion (%)										
Gut full % FLW	15^{ab}	13^{cd}	11^{d}	17^{a}	14^{bc}	12^{cd}	0.5	<.0001	<.0001	0.8171
Gut full % ELW	17^{ab}	14^{c}	12^{c}	18^{a}	15^{bc}	12^{c}	0.6	<.0001	<.0001	0.7387

^{abcd}Least square means with different superscripts are significantly different (P<0.05). Probability values (*P*-value): Graz+C00 =grazing alone as control; Graz+C50= grazing + 50 % *ad libitum* concentrate intake; Hay+C100 = (*ad libitum* hay + *ad libitum* concentrate intake); Standard error of mean (SEM); B = Breed; D = Diet; B*D = Interaction effect; Final Liveweight(FLW); Empty Liveweight(ELW); Total fat = fat from trimmed small intestines, pluck and kidney.

Appendix 27: LSMeans for the effect of breed and diet on carcass linear measurements and EUROP carcass classification on the individual treatment in Expt. 2

Parameter	Boran			Tanzania shorthorn zebu			SEM	*P - Value*		
	Graz+C00	Graz+C50	Hay+C100	Graz+C00	Graz+C50	Hay+C100		B	D	B*D
Carcass measurements (cm)										
Carcass length	108^{a}	108^{a}	110^{a}	97^{b}	100^{b}	106^{a}	1.5	0.0032	0.0064	0.0147
Chest depth	52^{ab}	53^{a}	56^{a}	47^{b}	48^{a}	52^{ab}	1.6	0.0775	0.0203	0.9126
Limb Circ.	62^{b}	66^{b}	72^{a}	53^{c}	58^{b}	67^{ab}	1.8	0.0043	0.0001	0.4558
Fat thickness	1.9^{cd}	3.0^{bc}	4.6^{a}	1.4^{d}	2.9^{c}	4.3^{a}	0.3	0.5644	0.0001	0.7000
Back fat	0.8^{c}	0.8^{c}	1.6^{ab}	0.5^{c}	1.0^{b}	2.2^{a}	0.2	0.7267	0.0001	0.0054
LD muscle area (cm^{2})	52^{b}	56^{ab}	61^{a}	40^{c}	49^{b}	53^{ab}	2.8	0.0003	0.0008	0.6429
Carcass EUROP Classification										
Carcass conformation	6.3^{c}	9.2^{b}	12.4^{a}	7^{c}	8.5^{b}	11.8^{a}	0.3	0.0341	0.0001	0.2154
Carcass fatness	2^{c}	3^{b}	4^{a}	2^{c}	3^{b}	4^{a}	0.2	0.5272	0.0001	0.1240
Carcass meat colour	4.3^{a}	3.8^{b}	2.8^{c}	4.5^{a}	3.5^{b}	3^{bc}	0.1	0.3914	0.0001	0.7810

^{abc} LSMeans with different superscripts in the same row are significantly different($P<0.05$). P-value = Probability values; Graz+C00 =grazing alone as control; Graz+C50= grazing + 50 % *ad libitum* concentrate intake; Hay+C100 = (*ad libitum* hay + 100 % of the *ad libitum* concentrate intake); Standard error of mean (SEM); B = Breed; D = Diet; B*D = Interaction effect; Limb circumference (Circ.); Carcass conformation score (1-15); Carcass fatness score (1-5) and Carcass meat colour score (1-5).

Appendix 28: LSMeans of the effect of breed and diet on carcass physical composition of individual treatments in Expt. 2

Parameter	Boran			Tanzania shorthorn zebu				*P - Value*		
	Graz+C00	Graz+C50	Hay+C100	Graz+C00	Graz+C50	Hay+C100	SEM	B	D	B*D
Weight of 6th rib Joints components (kg)										
Rib	2.9^{c}	3.4^{b}	3.3^{a}	3.2^{c}	3.3^{bc}	4.0^{a}	0.1	0.0335	<.0001	0.0128
Lean	2.0^{b}	2.2^{ab}	2.0^{a}	2.2^{b}	2.1^{b}	2.7^{a}	0.1	0.2621	<.0001	0.0181
Fat	0.2^{c}	0.5^{b}	0.8^{a}	0.2^{c}	0.6^{a}	0.9^{a}	0.03	0.8892	<.0001	0.9491
Bone	0.7	0.6	0.5	0.7	0.6	0.6	0.01	0.9701	0.1203	0.6910
Percent composition of 6th Rib										
Lean	69	67	62	69	65	68	2.0	0.5668	0.2712	0.3156
Fat	6^{c}	14^{b}	23^{a}	8^{c}	18^{ab}	21^{a}	2.0	0.9538	<.0001	0.6358
Bone	25^{a}	19^{bc}	15^{cd}	23^{a}	18^{c}	14^{d}	1.5	0.2655	<.0001	0.1168
Ratios of 6th Rib composition										
Lean:fat	11^{a}	4.7^{b}	2.7^{c}	9^{a}	3.7^{b}	3.2^{bc}	1.0	0.4009	<.0001	0.4321
Lean:bone	2.8^{b}	3.5^{b}	4.0^{b}	3.0^{b}	3.7^{b}	4.8^{a}	0.4	0.0907	0.0002	0.4755
Fat:Bone	0.3^{b}	0.8^{b}	1.5^{a}	0.3^{b}	1.0^{b}	1.5^{a}	0.1	0.1888	<.0001	0.3867

^{abcd} LSMeans with different superscripts are significantly different ($P<0.05$). *P*-value = Probability values Standard error of mean (SEM); Graz+C00 =grazing alone as control; Graz+C50= grazing + 50 % *ad libitum* concentrate intake; Hay+C100 = *ad libitum* hay + 100 % of the *ad libitum* concentrate; Standard error of mean (SEM); B = Breed; D = Diet; B*D = Interaction effect;

Appendix 29: LSMeans of the effect of breed and diet on temperature decline of Longissimus dorsi (LD) of carcasses from Expt. 2

		Temperature (°C) readings					
Breed	**Diets**	**45 minutes**	**6 h**	**24 h**	**48 h**	**Tdrop 1**	**Tdrop 2**
	Graz+C00	38.6[b]	26.0[c]	2.8[b]	2.3[a]	12.6[a]	23.3[b]
Boran	Graz+C50	39.3[ab]	28.1[b]	3.3[b]	2.5[ab]	11.2[b]	24.8[b]
	Hay+C100	40.2[a]	30.0[a]	3.9[a]	2.6[a]	10.2[c]	26.1[a]
	Graz+C00	36.8[c]	24.9[c]	2.9[b]	2.0[b]	11.9[ab]	22.0[c]
TSHZ	Graz+C50	38.5[b]	27.3[bc]	3.2[a]	2.4[a]	11.2[b]	24.8[b]
	Hay+C100	40.1[a]	30.2[a]	3.5[a]	2.6[a]	10.3[c]	26.7[a]
SEM		0.3	0.2	0.2	0.2	0.3	0.3
	B	0.0494	0.0206	0.4983	0.3148	0.9001	0.2081
P-value	D	<.0001	<.0001	0.0036	0.0781	<.0001	<.0001
	B*D	<.0001	0.0434	0.5070	0.7745	0.3608	0.0215

[abcd] LSMeans with different superscripts in the same column are significantly different ($P<0.05$). *P*-value = Probability values: Graz+C00 =grazing alone as control; Graz+C50= grazing + 50 % *ad libitum* concentrate intake; Hay+C100 = *ad libitum* hay + *ad libitum* concentrate intake: Standard error of mean (SEM): Tdrop 1 = Temperature drop from 45 min to 6hrs; Tdrop 2 = Temperature drop from 6hrs to 24hrs; B = Breed; D = Diet; B*D = Interaction effect:

Appendix 30: LSMeans of the effect of breed and diet on pH changes of Longissimus dorsi (LD) of carcasses from Expt. 2

		pH readings					
Breed	**Diets**	**45 minutes**	**6 h**	**24 h**	**48 h**	**pHchange1**	**pHchange2**
	Graz+C00	6.50	6.00	5.63	5.58	0.50	0.37
Boran	Graz+C50	5.52	5.94	5.62	5.57	0.42	0.32
	Hay+C100	6.45	5.9	5.6	5.55	0.55	0.30
	Graz+C00	6.36	5.88	5.60	5.62	0.48	0.28
TSHZ	Graz+C50	6.40	5.84	5.59	5.55	0.56	0.25
	Hay+C100	6.47	5.81	5.61	5.60	0.66	0.20
SEM		0.10	0.06	0.02	0.02	0.07	0.07
	B	0.1043	0.4477	0.8683	0.3863	0.4616	0.4067
P-value	D	0.8403	0.1529	0.0153	<.0001	0.0833	0.0205
	B*D	0.3922	0.9017	0.0953	0.5611	0.3324	0.7774

[abc] LSMeans with different superscripts in the same column are significantly different (P<0.05). *P*-value = Probability values; Graz+C00 = grazing alone as control; Graz+C50 = Graz+C00 + 50 % *ad libitum* concentrate intake; Hay+C100 = *ad libitum* hay + *ad libitum* concentrate intake; Standard error of mean (SEM); pHchange1 = pH change from 45 min to 6hrs; pHchange2 = pH change from 6hrs to 24hrs; B = Breed; D = Diet; B*D = Interaction effect

Appendix 31: LSMeans of the effect of breed and diet on percentage drip, thawing, cooking looses and shear force of LD of carcasses from Expt. 2

Breed	Diets	Drip loss (%)	Thawing loss (%)	Cooking loss (%)	Shear force (N)
		Meat quality attributes			
	Graz+C00	3.9	6.3	23.0^{a}	61.2^{a}
Boran	Graz+C50	3.7	5.8	18.4^{b}	47.8^{c}
	Hay+C100	3.4	4.7	17.2^{bc}	44.9^{c}
	Graz+C00	3.6	5.9	24.9^{a}	57.7^{a}
TSHZ	Graz+C50	3.0	5.6	23.1^{a}	54.0^{b}
	Hay+C100	2.8	4.0	16.2^{c}	57.7^{a}
	SEM	0.5	0.8	1.6	2.5
	B	0.1359	0.5344	0.1497	0.6873
P-value	D	0.3397	0.3291	<.0001	<.0001
	B*D	0.9304	0.2812	0.2043	0.1448

^{abc} LSMeans with different superscripts in the same column are significantly different (P<0.05). *P*-value = Probability values; Graz+C00 = grazing alone as control; Graz+C50 = Graz+C00 + 50 % *ad libitum* concentrate intake; Hay+C100 = *ad libitum* hay + *ad libitum* concentrate intake; TSHZ = Tanzania shorthorn zebu; Standard error of mean (SEM); B = Breed; D = Diet; B*D = Interaction effect.

Appendix 32: LSMeans of the effect of breed and ageing time (days) on percentage thawing loss, cooking loss and shear force on muscle LD of carcasses from Expt. 2

Breed	Ageing time (days)	Meat quality attributes: Thawing loss (%)	Cooking loss (%)	Shear force (N)
	2	8.0[a]	21.3	63.7[a]
Boran	10	4.3[b]	18.3	50.4[b]
	20	4.5[b]	18.9	39.8[d]
	2	6.0[ab]	17.7	68.5[a]
TSHZ	10	4.6[b]	24.4	48.8[c]
	20	4.9[b]	22.1	39.0[d]
	SEM	0.8	1.4	1.8
	B	0.5344	0.1497	0.6873
P-value	A	0.0005	0.4216	<.0001
	B*A	0.1769	0.0026	0.0568

[abc] LSMeans with different superscripts in the same column are significantly different (P<0.05). *P*-value = Probability values; Standard error of mean (SEM); B = Breed; A = Ageing time (days); B*A = Interaction effect

Appendix 33: LSMeans of the effect of diet and ageing time (days) on percentage thawing, cooking losses and shear force on LD of carcasses from Expt. 2

Ageing time	Diet	Meat quality attributes		
		Thawing loss (%)	Cooking loss (%)	Shear force (N)
	Graz+C00	8.8	22.4[b]	72.3[a]
2 days	Graz+C50	6.1	19.7[cd]	68.9[a]
	Hay+C100	6.3	16.4	57.2[b]
	Graz+C00	4.3	27.3[a]	58.8[b]
10 days	Graz+C50	4.5	20.3[c]	47.5[c]
	Hay+C100	4.4	16.5[de]	42.5[d]
	Graz+C00	5.2	22.1[bc]	47.4[c]
20 days	Graz+C50	4.8	22.3[b]	36.2[e]
	Hay+C100	4.0	17.2[e]	34.6[f]
	SEM	0.9	1.8	2.6
	A	0.0005	0.1497	<.0001
P-value	D	0.3291	<.0001	<.0001
	A*D	0.4717	0.2691	0.0358

[abcdef] LSMeans with different superscripts in the same column are significantly different (P<0.05). Probability values (*P*-value); Graz+C00 = grazing alone as control; Graz+C50 = Graz+C00 + 50 % *ad libitum* concentrate intake; Hay+C100 = *ad libitum* hay + *ad libitum* concentrate intake; Standard error of mean (SEM); D = Diet; A = Ageing time (days); D*A = Interaction effect

Appendix 34: Inputs and their costs used in Expt. 2

ITEM	Quantity	Unit price (Tshs)	Amount (Tshs)
1.0 Animals and costs			
Animals	*Numbers*		*Amount (Tshs)*
Boran	36	318.150	11.453.400.00
Tanzania shorthorn zebu	36	270.000	9.720.000.00
	Sub total		21.173.400.00
2.0 Feeds and costs			
Type of feeds	*Amount (kg)*		
(i) Concentrate mixture			
Maize	8944	480	4.295.200.00
CSC	2799	398	1.113.602.57
Molasses	6783	205	893.658.21
Mineral mix	330	1750	577.500.00
Salt	418	300	125.400.00
Urea	80	1000	80.000.00
Mineral blocks	108	1900	205.200.57
(ii) Cut hay	4860	120	633.782.61
(iii) Grazed forage	14800	74	1.095.200.00
	Sub total		9.019.543.97
3.0 Labour (wages)			1.402,608.00
4.0 Veterinary drugs and services			450,000.00
5.0 Transport costs animals - market & abattoir			1,000,000.00
6.0 Fixed cost due to feedlot structure and feed store			311.252.00
	TOTAL COSTS		33,356,803.97

Note: USD 1 was equivalent to 1.310/= Tanzania shillings as per 20th Nov.2009

Appendix 35: Total costs of input costs used for individual treatment in Expt. 2

Breed		**Boran**			**Tanzania shorthorn zebu**	
Finishing Diets	**Graz+C00**	**Graz+C50**	**Hay+C100**	**Graz+C00**	**Graz+C50**	**Hay+C100**
Number of animals	**12**	**12**	**12**	**12**	**12**	**12**
1.0 Cost of animals	3,817,800	3,817,800	3.817.800	3.240.000	3.240.000	3,240.000
2.0 Costs of feed	370000	1564465	2939420	370000	1528950	2631502
3.0 Cost of Labour (wages)	91169.52	119222	490913	91169.52	119222	490913
4.0 Veterinary drugs and services	75,000	75,000	75.000	75.000	75.000	75.000
5.0 Transportation	166667	166667	166667	166667	166667	166667
Total variable costs	4520636	5743154	7489800	3942836	5129845	6604082
6.0 Fixed costs due-Feedlot	0	77813	77813	0	77813	77813
Total costs	4520636	5820967	7567613	3942836	5207658	6681895

Note: USD 1 is equivalent to Tanzania shillings 1310 as per 20th Feb .2009; Graz+C00 = grazing with no concentrate as control; Graz+C50 = Graz+C00 + 50 % *ad libitum* concentrate intake; and Hay+C100 = *ad libitum* hay + *ad libitum* concentrate intake.

Appendix 36: Estimated unit cost of production per kilogram of carcass for individual treatment in Expt. 2

Finishing Diets	Boran			Tanzania shorthorn zebu		
	Graz+C00	Graz+C50	Hay+C100	Graz+C00	Graz+C50	Hay+C100
Total costs (TC)	4520636	5820967	7567613	3942836	5207658	6681895
TVC	4520636	5743154	7489800	3942836	5129845	6604082
ASW	214	254	309	167	202	257
ADP	46	51	55	48	51	54
AHCW	111	125	160	83	103	139
PC(kg)/treatment	1332	1500	1920	996	1236	1668
UC /kg carcass	3394	3881	3941	3959	4213	4006

Note: USD 1 is equivalent to 1,310 Tanzania shillings as per 20th Feb .2009; TVC=Total variable costs; ASW =Average slaughter weight; ADP = Average dressing percentage; AHCW =Average hot carcass weight; PC =Carcass produced (kg); UC = Unit cost; Graz+C00 = grazing with no concentrate as control; Graz+C50 = Graz+C00 + 50 % *ad libitum* concentrate intake and Hay+C100 = *ad libitum* hay + *ad libitum* concentrate intake.

Appendix 37: LSMeans of the effects of breed and diet on production costs and Net Returns (TSH per carcass) on finished steers in Expt. 2

Parameter		**Case 1** (Net returns 1)	**Case 2** (Net returns 2)	**Case 3** (Net returns 3)
Breed	Boran	-35478[a]	225893[a]	439642[a]
	TSHZ	-60622[b]	170102[b]	351602[b]
	SEM	0.12	0.03	0.14
	P – Value	<.0001	<.0001	<.0001
Finishing Diets	Graz+C00	-13145[a]	-	-
	Graz+C50	-60526[b]	167474[b]	338474[b]
	Hay+C100	-70479[c]	226564[a]	448627[a]
	SEM	0.42	0.41	10.23
	P - Value	<.0001	<.0001	<.0001

Note: USD 1 was equivalent to Tanzania shillings 1310/= as per 20[th] Feb .2009; [abc] LSMeans with different superscripts in the same column are significantly different (P<0.05). *P*-value =Probability values; NRs 1 = Net Returns when carcass sold at 3500/= Tshs/kilo; NRs 2= Net Returns when carcass sold at 5500/= Tshs/kilo; NRs 3= Net Returns when carcass sold at 7000/= Tshs/kilo; Graz+C00 =grazing alone as control; Graz+C50= grazing + 50 % *ad libitum* concentrate intake; and Hay+C100 = *ad libitum* hay + 100 % of the *ad libitum* concentrate intake; Tanzania shorthorn zebu (TSHZ).

Appendix 38: Net returns (NRs) and Gross margin (GM) for individual treatments in Expt. 2

Parameter				Boran			Tanzania shorthorn zebu		
				Graz+C00	Graz+C50	Hay+C100	Graz+C00	Graz+C50	Hay+C100
Av. hot carcass weight (kilogram)				111	125	160	81	103	139
Unit cost /kilogram carcass				3394	3881	3941	3959	4150	3959
Unit variable cost /kilogram carcass				3394	3829	3901	3959	4213	4006
Total production costs per steer (Tshs)				376720	485081	630634	328570	433971	556825
Total variable costs per steer (Tshs)				376720	478596	624150	328570	427487	550340
		Sale Price Tshs/kilogram							
Case 1	TR	Used	3500	388500	437500	560000	290500	360500	486500
	GM (Tshs/carcass)			11780	-41096	-61150	-38070	-66987	-63840
	NRs (Tshs/carcass)			11780	-47581	-70634	-38070	-73471	-70325
Case 2	TR	Assumed	5500		687500	880000		566500	764500
	GM (Tshs/carcass)				208904	255850		139013	214160
	NRs (Tshs/carcass				202419	249366		132529	207675
Case 3	TR	Assumed	7000		875000	1120000		721000	973000
	GM (Tshs/carcass)				396404	495850		293513	422660
	NRs (Tshs/ carcass)				389919	489366		287029	416175

Note: USD 1 is equivalent to Tanzania shillings 1.310 as per 20[th] Feb .2009; Graz+C00 = grazing with no concentrate as control; Graz+C50 = Graz+C00 + 50 % *ad libitum* concentrate intake and Hay+C100 = *ad libitum* hay + *ad libitum* concentrate intake; TR = Total revenue; NRs = Net Returns; GM = Gross margin